DEPARTMENT OF THE INTERIOR
UNITED STATES RECLAMATION SERVICE
IN COOPERATION WITH
STATE OF OREGON

OREGON COOPERATIVE WORK

Warner Valley and White River Projects

(IRRIGATION AND DRAINAGE)

BY

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WARNER VALLEY AND WHITE RIVER PROJECTS.

SYNOPSIS.

(1) This report is the seventh of a series of reports on what is designated as "Oregon Cooperative Work," being preceded by reports on the following projects: Deschutes, Ochoco and Crooked River Investigations, Silver Lake, John Day, Malheur and Owyhee, and Harney and Silver Creek. It deals with the irrigation and water-power possibilities of the Warner Valley region, Lake County, and includes a report of preliminary investigations on White River, Wasco County.

(2) Funds for the Oregon Cooperative Work were provided by an appropriation of $50,000 by the State and the allotment of an equal amount by the Secretary of the Interior from the reclamation fund. This money was appropriated for the purpose of promoting irrigation and power development in Oregon. The work has been carried on by the United States Reclamation Service and the Oregon State engineer's office under an agreement referred to in this report.

WARNER VALLEY PROJECT.

(3) The development proposed by this project is the drainage of 46,000 acres of swamp land in Warner Valley, the irrigation of 33,000 acres of these lands in the south end by gravity canals, and pumping to irrigate 27,000 acres in the north end.

(4) The features to which this report has special reference are:

(*a*) The reclamation of about 33,000 acres of land in South Warner Valley by dredged channels for drainage and gravity canals from Deep Creek to serve these lands during irrigation.

(*b*) The reclamation of 27,000 acres in North Warner Valley by a drainage channel to serve 13,000 acres of these lands and control excess water, and by pumping to irrigate the entire 27,000 acres.

(*c*) The development of 2,000 electrical horsepower on Deep Creek for operating dredges during construction and to furnish power to four pumping plants in North Warner Valley on completion of the project.

(*d*) Provision for ample storage in Big Valley and Coleman Valley to insure the reclamation of the marshlands in years of extreme run-off.

The probable cost of this development as outlined is $1,726,000, or about $29 per acre.

(5) The records of discharge for the streams entering Warner Valley are fairly complete for six years. From these records it is estimated that the mean annual run-off to the valley is 195,000 acre-feet, with a maximum of 308,000 acre-feet in the seasonal year 1910 and a minimum of 84,000 acre-feet in the seasonal year 1915. The extreme maximum run-off, however, may be expected to reach nearly 600,000 acre-feet.

(6) Practically all the summer flow of the streams entering the valley in ordinary years is now appropriated; a large part of this use is on marsh and hay lands where the streams enter the valley.

(7) Considerations of possible extreme run-off and the disposition of these waters to insure the reclamation of the marsh lands make it appear advisable to furnish at least 210,000 acre-feet storage in addition to the volume of water which may be stored in the bottom of Crump and Hart Lakes and in Bluejoint and the lakes of the Flagstaff Lake district at elevations which would not back up the water sufficiently to flood the marsh lands.

(8) Considerations of water supply and cost of storage development at the various reservoir sites have led to the adoption for this report of storage plans as follows:

	Acre-feet.
Big Valley, on Deep Creek	100,000
Coleman Valley	60,000
Cowhead Lake	75,000
Total storage	235,000

(9) The disposition of a large quantity of excess water in years of abnormal run-off may be best accomplished by connecting Bluejoint and Flagstaff Lakes with dredged channels so that the largest possible area of water surface may be exposed to evaporation when desired. The amount possible to dispose of in this manner is estimated at 105,000 to 125,000 acre-feet in a single season.

(10) So far as Warner Valley interests are concerned, the benefit that will be derived in years of extreme run-off from the proposed Cowhead Lake storage development, with diversion of the headwaters of Twentymile Creek into Cowhead Lake and the use of this stored water in Surprise Valley, as planned by the Modoc County Irrigation Co., will probably be greater than the loss which will occur through the small amount so diverted in years when there may be a shortage in Warner Valley, provided that in such development there is ample capacity in diversion canals and ample storage capacity in Cowhead Lake to hold back from Warner Valley a large portion of the water which might otherwise enter the valley in years of

extreme run-off. The storage capacity to be provided at Cowhead Lake should probably be not less than 75,000 acre-feet.

(11) The mean yearly discharge of Deep Creek at Big Valley is estimated to be 52,000 acre-feet, and a possible extreme run-off of 100,000 acre-feet may be expected. From considerations of flood control for reclamation of marsh lands, storage capacity should be provided at Big Valley for at least 100,000 acre-feet. The cost of such storage development is taken as $187,500, or $1.87 per acre-foot of storage capacity. With the estimated mean yearly run-off of 52,000 acre-feet and losses by seepage and evaporation of 9,000 acre-feet, the available supply in ordinary years would be 43,000 acre-feet, or an apparent cost per acre-foot at diversion of but $4.35, even with the large capacity reservoir. This is a much smaller cost than for any of the other reservoir sites considered.

(12) A detailed study of the records of discharge of the three streams entering Warner Valley during the extreme low year, 1914–15, indicates shortages from the mean yearly supply as follows: Deep Creek, 57 per cent; Twentymile Creek, 47 per cent; Honey Creek, 66 per cent. Considering Big Valley and the remainder of the area drained by Deep Creek, the following shortages are found: Big Valley, 38 per cent; Camas Creek and Drake Creek combined, 65 per cent. It thus appears that Big Valley is the most feasible storage site, not only from the point of cost per acre-foot capacity, but from that of more dependable supply in years of small run-off.

(13) Coleman Valley, which is lower than any part of Warner Valley proper, offers an excellent site for the disposition of excess water in years of extreme run-off, in conjunction with the proposed plan of crossing the valley east of Adel with the feed canal for the marshlands on the east side of the valley. A branch canal about 9.5 miles long from this canal to Coleman Valley will serve to conduct early flood waters to Coleman Valley; 60,000 acre-feet can be run into Coleman Valley in this manner. The area exposed to evaporation when the valley is filled to this capacity is about 5,000 acres, and the probable yearly evaporation from this area is estimated to be 16,500 acre-feet.

(14) There is also an opportunity to increase this storage capacity to 110,000 acre-feet by building a 10-foot dike with controlling gates across a narrow place in the Coleman Valley entrance. A pumping plant would be required to lift water from the supply canal through a 10-foot lift to the reservoir. No additional power development would be required on Deep Creek, as the power would be used prior to the irrigating season and would be supplied by the plant which is proposed for the furnishing of power for pumping in North Warner Valley. However, the required use of this additional storage would

come only in occasional years of maximum run-off and is not believed to be necessary, unless as an alternative for the Cowhead Lake storage development.

(15) There are power possibilities on all of the streams entering Warner Valley, but Deep Creek offers the best opportunity on account of the larger run-off and the smaller variation in run-off from year to year. Some 850 feet of fall in Deep Creek can be utilized by power canals totaling about 6 miles in length. This drop occurs in two places, separated by about 4 miles of flatter grade in the stream bed above the Deep Creek Falls.

(16) The total of power possibilities on Deep Creek, in conjunction with Big Valley storage as planned for the proposed project, is approximately 3,500,000 horsepower days in years of ordinary run-off, this being with a possible minimum continuous power of 1,550 horsepower for the entire year and 29,400 horsepower for a 100-day period.

(17) With additional storage at the Mud-Camas Reservoir site to regulate minimum flow, the power available for commercial use on an all-the-year basis is 3,780 horsepower, with a balance of 21,200 horsepower available for a 100-day period. The summer power possibility at either power site is far in excess of the probable ultimate requirements for pumping to the Warner Valley lands.

(18) The apparent cost of developing summer power for pumping is $60 per horsepower of generator output, and that for commercial power to the extent of 3,780 horsepower requiring the Mud-Camas storage development is $125 per horsepower generator output.

WHITE RIVER PROJECT.

(19) This project is located to the south and east of the Oregon National Forest, in the vicinity of Mount Hood. The lands which it is proposed to irrigate, about 36,000 acres, lie on both sides of White River above its junction with the Deschutes, and in general between Wapinitia Creek on the south and Badger Creek and Tygh Creek on the north, mainly in T. 4 S., Rs. 12, 13, and 14 E., and T. 5 S., Rs. 11, 12, and 13 E., as shown on Plate IV, White River project.

(20) The investigations included a general reconnoissance of the region to determine the water supply, the extent and location of the irrigable areas, and the cost of getting water to them, including an estimate of the value of existing development and water rights on the various streams.

(21) The drainage basin has an area of about 350 square miles and is largely forested in the upper regions of White River and tributary streams. Complete records of run-off are short, covering a period of but four years. The mean annual run-off of White River near Tygh

Valley for the period is about 234,000 acre-feet, the maximum occurring in the seasonal year 1911–12 with 297,000, and the minimum in 1914–15 with 163,000 acre-feet. The maximum recorded rate of discharge was 2,050 second-feet in January, 1912, the minimum 82 second-feet in September, 1915, the mean average rate for the irrigating season being about 300 second-feet, with a minimum average of 175 second-feet in 1915.

(22) Climatological conditions are in general favorable to irrigation. Precipitation in the region of the irrigable area is about 14 inches annually, with about 3.3 inches during the irrigating period. Temperature ranges, while high, are offset by the mitigating conditions of dryness and altitude which prevail in the interior of the State. The growing season lasts from four and a half to five months.

(23) The soil, while shallow in places, is of fairly good quality and well adapted to irrigation. The percentage of waste land in the gross irrigable area is rather large, however, and the distributing system will, on this account, be more expensive. Drainage, which in some localities may be necessary, will not be difficult, as the topography of the region lends itself to an inexpensive system.

(24) Under the plan of diverting water from White River supplemented by storage in Clear Lake, and on the north side adding the flow of Gate Creek, Rock Creek, and Threemile Creek to the supply for distribution, an available 80,000 acres gross and approximately 40,000 acres, net area, of irrigable land were found about Smock and Wamic, on the north side of the river, and on Juniper Flat, on the south.

(25) With an assumed duty of 1.5 acre-feet delivered to the land during the irrigating season, the plan of development includes:

(*a*) A storage reservoir in Clear Lake with a capacity of 18,000 acre-feet, furnishing 12,000 acre-feet net storage supply.

(*b*) A diversion dam at the mouth of Boulder Creek.

(*c*) Two diversion canals—the one on the north being 8 miles long with a capacity of 130 second-feet, to water approximately 13,000 acres, and the one on the south side of White River being 10 miles long with a capacity of 230 second-feet, to water approximately 23,000 acres.

(*d*) Distributing system for about 36,000 acres net.

(26) The apparent cost of this proposed development of 36,000 acres is $36 per acre irrigated, including purchase of White River power plant.

(27) If storage is eliminated a water supply could probably be obtained sufficient to irrigate 15,000 acres on the north side of the river for $47.20 per acre, or on the south side 14,000 acres could be

watered at a probable cost of $51.30 per acre, the increased cost per acre being due to smaller area to which the cost of White River power plant can be charged.

(28) Storage sufficient to supply 2,500 additional acres of irrigable land could be developed on Gate Creek at a probable cost of $10 per acre-foot of water delivered.

(29) Existing water rights and development work were investigated, and an estimate made of their probable value, White River power plant and the Wapinitia Irrigation Co.'s holdings being of chief interest.

(30) Investigations of the possibilities of irrigating the bench lands between Badger Creek and Threemile Creek, and those between Threemile Creek and Rock Creek with waters from those creeks, the run-off being regulated by storage on Threemile Creek, showed sufficient water supply for a net average irrigable acreage of 7,500 acres included in a gross area of 15,000 acres. The cost of the reservoir and distributing canal system, amounting to a total of over $95 per acre of lands served, makes this scheme economically impracticable at the present time.

(31) Investigations of Tygh Valley bench lands showed 3,000 to 4,000 acres of irrigable land, but the complication of water rights involved in their irrigation with water from Badger and Tygh Creeks renders impossible at the present time any definite conclusion as to its feasibility.

(32) The conclusions reached as the result of these investigations are that this project as outlined, in the nature of conditions surrounding it, will become attractive only with the growth of a demand for irrigation sufficient to make economically desirable the absorption of all other claims to the available water supply.

INTRODUCTION.

AUTHORITY.

Authority for Oregon Cooperative Work and this report is found in the act of Congress of June 17, 1902 (32 Stat., 388), commonly known as the reclamation act, and subsequent, supplementary, and amendatory acts, on the part of the United States, and an act of the legislature, chapter 87, General Laws of Oregon, 1913, on the part of the State of Oregon. Copies of the reclamation act and its amendments by Congress may be had on application to the United States Reclamation Service, Washington, D. C. The State law authorizing this work was quoted in the Deschutes project report published in 1914, and need not be given here.

AGREEMENTS.

Agreement May 5, 1913.—Under authority of these acts of Congress and of the State legislature an agreement was entered into between the United States and the State of Oregon through the Secretary of the Interior, Franklin K. Lane, and the State engineer, John H. Lewis, under date of May 5, 1913, which provides for the manner of carrying on the investigations. This agreement is given in full in the Deschutes report, copies of which can be obtained on application to the United States Reclamation Service or to the State engineer, and will not be repeated here. In general this agreement provides:

(1) That surveys and investigations for irrigation projects, with incidental power possibilities, be made in central Oregon.

(2) That from time to time during the investigations withdrawals of public lands and of unappropriated waters be made by the Secretary of the Interior and the State engineer, respectively, as may appear in their judgment advisable to protect the development of any project proposed for irrigation.

(3) That all investigations be made under plans agreed upon by the Reclamation Service and the State engineer.

(4) That the field notes and data acquired or prepared be filed with the Reclamation Service, accessible at all times to the State engineer or his representatives.

(5) That on completion of the investigations a report be published, with conclusions and recommendations.

(6) That the expense of the work be equally divided between the United States and the State of Oregon.

(7) That employees paid by the United States and the State shall be subject to rules and regulations established by each respectively, and that in the selection of employees preference be given to residents of the State.

Agreement April 15, 1915.—After having completed investigations of Deschutes, Owyhee, and Silver Lake projects of central Oregon, it appeared desirable to extend the investigations to include territory west of the Cascade Mountains as well as east of the mountains, and a second agreement was therefore entered into between the United States and the State providing that investigations might be made in any part of the State.

Provision was also made in this second agreement for use of data already obtained by the Reclamation Service, conditional upon the value of data for any particular project being returned to the United States by whomever might take up the project for construction. The value of this data was agreed upon as $25,000, and was furnished to the cooperative work under the terms of the agreement in addition to the $50,000 provided by the United States under the first agreement.

This agreement is given in full in the John Day project report, which can be obtained on application to the United States Reclamation Service or the State engineer.

ORGANIZATION FOR THESE INVESTIGATIONS.

Field surveys and office studies on which this report is based have been made by Federal and State engineers in conformity with the general plan provided under agreements between the United States and the State governing Oregon Cooperative Work. The work has been done and the report prepared under direction of John T. Whistler, engineer, United States Reclamation Service, in conference with John H. Lewis, State engineer, and the report is subscribed to by them on behalf of the cooperating Federal and State authorities.

Attention is directed to the fact that the subscription to this report by officers of the Reclamation Service and the State does not commit other officials of the Government or of the State to the conclusions reached herein.

In making the investigations and studies for the Warner Valley project the maps and other data collected by the Warner Lake Irrigation Co. at much expense have been placed at the disposal of Oregon cooperative work. In addition to these data, which in a general way have been checked in the field, certain additional topographical data have been collected, and also a soil survey prepared.

The field work and office computations for the Warner Valley project have been made by W. R. Parkhill, who has also largely

prepared the report itself. The soil examination was made by W. L. Powers, assistant professor of irrigation and drainage, Oregon Agricultural College. The early history of Warner Valley was written by Lewis A. McArthur, of Portland, and the chapter on water supply by Fred F. Henshaw, district engineer of the United States Geological Survey, Portland, Oreg. Use has also been made of report and maps by G. A. Waring, United States Geological Survey Water Supply Paper No. 220, "Geology and Water Resources of a Portion of South-Central Oregon."

The investigations for White River project were made by C. E. A. Bennett. The investigation consisted simply of hand level and aneroid barometer reconnoissances, and is not based on accurate topographic maps.

The investigations were taken up at the suggestion of A. N. Driver, T. P. Driver, A. G. Harvey, and F. S. Morrow, of Wamic, and K. L. Hauser and C. York Wilson, of Tygh Valley.

Field studies of agricultural possibilities of the district were made by W. L. Powers, assistant professor of agronomy, Oregon Agricultural College, Corvallis.

WARNER VALLEY PROJECT.

GENERAL CONDITIONS.

LOCATION AND GENERAL DESCRIPTION.

Warner Valley is located in south-central Oregon in the eastern part of Lake County. (See Plate No. 1.) The northern end of the valley reaches about 10 miles into Harney County, while the southern end extends nearly to the States of Nevada and California. The valley is about 60 miles long and 4 to 6 miles wide, increasing to a maximum width of about 8 miles to the north of the lakes of the Flagstaff Lake region. The elevation is about 4,400 feet above sea level.

Both sides of the valley as far north as Plush are formed by steep walls rising from 1,000 to 2,000 feet above the valley bottom, giving the valley the appearance of a deep trough formed by the dropping of a portion of the high table-land. The eastern wall is continuous to the north end of the valley, while the western wall north of Plush becomes a gentle slope reaching back to the mountains east of Lake Abert, this slope being broken by groups of hills, such as the Coyote and Rabbit Hills.

The valley bottom is occupied by a chain of lakes which have varied greatly in size even since the valley was first settled. At one time the entire bottom must have been one vast lake, which has gradually receded, leaving large marsh areas which support thousands of cattle and horses. The slope of the valley is toward the north end, the normal elevation of Bluejoint Lake being about 12 feet lower than Crump Lake. The greatest change in elevation, about 8 feet, occurs between Hart Lake and Anderson Lake. A contraction in the valley to the south of Hart Lake divides the valley into two parts, hereafter referred to as South Warner Valley and North Warner Valley.

The marsh areas are given over to summer grazing for stock, and some wild hay is cut for winter feeding. Much of the valley bottom from Plush northward is practically a desert, characterized by growths of greasewood and dwarf sage. With the exception of a narrow strip lying just below the steep slopes, the valley bottom is cut up by sand dunes and ridges separated by "slick" spots or, in the lower part between the lakes in the Flagstaff Lake region, by backwater sloughs from the different lakes. This area is probably unsuitable for irrigation development because of the roughness, poor soil, and danger of alkali conditions.

Sand ridges, often 50 feet high, form the abrupt shores of the lakes in the Flagstaff Lake region and of Bluejoint Lake. They occur generally on the north shores, which would indicate that these lakes have been dry at times, and southerly winds blowing the silt deposits to the north end have banked the sand to form these ridges, which have become covered with a heavy growth of greasewood.

Bluejoint Lake has been dry for the past two years, and the lakes of the Flagstaff Lake district are about 4 feet below their normal elevation, thus exposing below the ordinary beach line an expanse of lake bed from 500 to 1,000 feet wide. The similarity of this exposed lake bottom to the corresponding edges of Bluejoint Lake, which is now entirely dry, and the fact that cranes were seen wading at great distances from the shores, indicates the shallow character of these lakes, which would probably have become entirely dry during the past season had 2 feet more of water evaporated from the surface.

Hart Lake apparently varies least between extreme stages, and probably never goes dry, although the south half is comparatively shallow, as indicated by soundings made in 1912, the depth being only about 6 feet at normal level, while the north end is 14 feet deep. This lake receives the overflow from South Warner Valley, as well as the discharge of Honey Creek entering the valley from the west near Plush.

Crump Lake, located in South Warner Valley, is a comparatively small lake, at the present time covering but 1,250 acres. It is about 2 feet below normal stage, at which point it overflows into Hart Lake. Records of the past five years show that the lake has reached a level 4½ feet above the present stage, at which time the surrounding marsh lands were flooded to an estimated extent of about 10,000 acres, covering practically all of the unsurveyed portion of that part of the valley in which it is located. (See Plate No. 1.)

A well-defined channel from near the north end of Pelican Lake, in the form of a deep slough, winds through the marsh to Crump Lake. From this channel there are no well-defined water courses taking the discharge of Deep Creek and Twentymile Creek to Crump Lake. The waters of these streams in years of high run-off find their way through the marsh lands to Crump Lake. Dodson Lake is another small lake fed indirectly by the spring floods from Deep Creek and Twentymile Creek.

History.—The following notes on early history of Warner Valley were furnished by Lewis A. McArthur, of the Oregon Geographic Board:

It is possible that early trappers or voyageurs of the Hudson's Bay Co. may have visited Warner Valley before 1843, but the writer has been unable to find any trace of such a visit. A map of the

Oregon territory accompanying Senator Linn's report, prepared under the direction of Col. J. J. Abert in 1838, shows a river flowing from a lake near what we now call Warner Valley, the river being labeled "Christmas River." It is not clear where the data upon which this map was prepared were obtained, but it is a remarkable coincidence that five years later Capt. Frémont named one of the principal lakes of the Warner Valley Christmas Lake.

It was during the second exploring expedition of then Capt. John C. Frémont, of the United States Topographical Engineers, that the Warner Valley was visited and described in writing. This expedition left Kansas in May, 1843, and made its way to Oregon, passing The Dalles, and finally reaching Vancouver. Here the party began to retrace its steps, journeying back to The Dalles over the same route that it had just traveled.

Capt. Frémont and his party left the mission at The Dalles on November 25, 1843, and traveled in a southerly direction along the western part of the Deschutes Valley, finally reaching Klamath Marsh on December 10. Here the party turned eastward, and six days later reached and named Summer Lake.

On December 20 Frémont discovered and named Lake Abert in honor of Col. Abert, of the Topographical Engineers, who was his chief. Frémont came upon Lake Abert near the southern end and followed up the eastern shore until he reached a small valley near its northern extremity. Here he turned to the southeast, and his journals mention finding a lake at the foot of a high ridge, the lake being so surrounded with mud that it could not be closely approached. From an inspection of the Frémont maps it seems apparent that this was what is now known as Flagstaff Lake. A short distance to the south was another lake, the eastern shore of which Frémont reached on December 24. The next morning the lake was christened Christmas Lake, and the day was celebrated by giving the members of the party an allowance of brandy all around. The maps of the explorer indicate that this is what is now known as Hart Lake.

Frémont tells of a well-beaten Indian trail through the valley and mentions Indian camping grounds. More lakes were passed on December 26. The explorer mentions the fact that at high-water stages the lakes were probably connected, though at that time they were but little more than dry beds. On the night of December 26 camp was made on the forty-second parallel, which is now the Oregon-California line, well to the south of the last of the Warner Lakes.

During the next six years there seems to be no further record of Warner Valley, until Bvt. Capt. W. H. Warner and Lieut. R. S. Williamson were directed to explore the upper reaches of Pit River.

The party left Sacramento on August 13, 1849, and eventually reached the upper Pit River. The roughness of the country compelled the abandonment of the wheel vehicles.

Sickness, scarcity of pack animals, and the lateness of the season hindered the work, and finally Capt. Warner took a party of nine men and proceeded to the north along the west shore of Goose Lake, leaving Williamson camped at the lake. The Warner party passed along the east shore of Lake Abert, following the same route as Frémont, turned to the southeast at the northern end of the lake, reaching the Warner Valley probably not far from Mugwump Lake. Warner then worked south along the western part of the valley until September 26, 1849, when his party was ambushed by the Indians and Warner himself was killed. The scene of the massacre was probably just south of the State line, on Twentymile Creek. Williamson returned to headquarters with most of the data on the exploration, but only parts of the information have ever been published.

Transportation and markets.—The principal industry is stock raising. Some horses are raised for market, but beef is the chief product. Sheep are grazed in the north end of the valley to some extent but mostly on the higher table-lands, where water may be found. The flocks are wintered in the valley, and the wool is hauled by wagon across a high mountain range to Lakeview, a distance of 35 miles from Plush and 30 miles from Adel.

Lakeview is the terminus of the Nevada, California & Oregon Railroad, which connects with the main line of the Central Pacific at Reno, Nev., and the Western Pacific at Doyle, Nev. This branch line is a narrow-gauge railroad, and carload shipments have to be transshipped at the main-line junction points.

The Oregon Eastern extension of the Oregon-Washington Railroad & Navigation Co. has been recently constructed from Ontario, Oreg., to Riverside, in Malheur County. It is now being extended to Harriman, in Harney County. The location survey of this line extends westward through the Christmas Lake and Fort Rock Valleys to connect with the partly completed Natron cut-off from near Eugene to Klamath Falls. A preliminary survey has been made from the Oregon Eastern survey near Iron Mountain through Warner Valley from north to south and continuing to Surprise Valley in California. Access to Warner Valley from the north is comparatively easy, and railroad transportation can probably be expected in the future, following completion of a railroad through Harney Valley and development of sufficient freight traffic to warrant such a branch line, which would be approximately 40 miles long to reach the north end of the valley.

GENERAL INFORMATION.

CLIMATE.

The climate in Warner Valley is very similar to that of the entire high-plateau country of south-central Oregon, except as modified by the high escarpments forming the eastern rim of the valley throughout the entire length and the western rim as far north as the town of Plush. The absence of this rim on the west side of the valley north of Plush materially affects the climate of North Warner Valley and leaves it subject to the westerly and northwesterly winds, which in the spring and fall seasons sweep from the high table-lands and peaks lying between North Warner Valley and Lake Abert.

Fruit, such as pears, peaches, and apples, have been grown with moderate success in South Warner Valley for many years. A frost may be expected to destroy the more delicate fruits about once in three or four years. No fruit is produced in North Warner Valley. Two orchards have been set out in recent years under the east rim in the vicinity of the lakes of the Flagstaff Lake district, but have not reached the bearing stage. Two or three crops of alfalfa are cut on irrigated fields in the vicinity of Adel.

It is believed that the climatic conditions as a whole are very much the same as in Goose Lake Valley to the west and Surprise Valley to the south, although frost conditions may be less favorable in North Warner Valley. Some rain may be expected in May or June, but the summer and fall months are very dry and clear. Snowfall in the valley bottom is very light in the winter; the snow remaining on the ground but a short time. The higher table-lands may have several feet of snow, and the higher peaks, such as Drakes Peak, Warner Mountain, and Bidwell Peak, may have snow on them until midsummer and again in the early fall.

Air movements brought about by the unequal temperatures in the valley and on the higher table-lands and mountains give rise to daily winds which are strongest in the canyons entering the valley from the highlands. Such winds are very noticeable at Adel, located where Deep Creek Canyon enters the valley. The wind is strongest in the early morning.

Probable influence of climate on nature of crops.—The frequent occurrence of frosts in late spring and early fall probably restricts the growing season to an average of about 100 days. Under these conditions the principal crops that may be expected to be successfully grown are the hay crops, alfalfa, clover, and timothy; grains, such as wheat, oats, rye, and barley, and hardy root crops to some extent.

Three crops of alfalfa can probably be raised over the larger part of South Warner Valley, while the less favorable climatic conditions

in North Warner Valley may make two crops the most that can be depended upon.

GEOLOGY.

The earliest account of the geology of the Warner Valley region is given by I. C. Russell, and may be found in the Fourth Annual Report of the United States Geological Survey, 1882–83. Russell's reconnoissance of this valley in 1882 took him entirely around the valley. No better description of the geology can be given than to quote from his report. Crooks Bridge, referred to in the following quotation, is locally known as Stone Bridge, located at the narrow inlet to Hart Lake at the south end of that lake. (See Plate No. 1.) In describing the Warner Valley fault Russell says:

> The valley of the Warner Lakes and Long Valley to the southward together form a single narrow belt of diverse displacement that is fully 100 miles in length. The exhibition of fault scarps, tilted blocks, and sunken areas, to be seen at the southern end of the Warner Lakes, is the most interesting of its kind that it has ever been our privilege to examine. In this narrow zone the orthographic blocks of dark volcanic rock are literally tossed about like the cakes in an ice floe, their upturned edges forming bold palisades that render the region all but impassable. The main line of displacement is along the foot of the perpendicular cliffs that border the Warner Lakes on the east. Midway a large branch with reverse throw crosses to the west side of the lakes and gives origin to the high bluffs that extend from Crooks Bridge southward. These fault scarps rise in sheer precipices that overshadow the Warner Lakes throughout their entire extent. Toward the northern end of the valley the great fault scarp forming its eastern wall sends off a number of branches at quite regular intervals with a general northwest trend. The blocks thus separated pass under the lake beds that floor the valley, and appear again on its western border, where they form cliffs of considerable height. Their acute ends are visible at the point of bifurcation; and the apex of a thin wedge of rock clings high on the edge of the great fault scarp, while its base is buried in the lake beds in the bottom of the valley. This is but one of the slivers rent off by the great fracture. The great fault scarp itself finally became lost at the northward in subdivisions.
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> The country to the north and east is a rough volcanic table-land that has undergone considerable erosion, and indicates the nature of the plateau of which the region of the Warner Lakes formed a part before it was faulted. * * *
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> In the southern part of the Warner Lakes Valley the structure is more complex, as the basin is bounded on each side by perpendicular cliffs of displacement from 1,500 to 2,000 feet high, while the included area is broken by both north-and-south and east-and-west faults. * * *
>
> It is between the high walls inclosing the southern portion of the valley that the greatest confusion of the minor blocks is to be seen. Many of these fragments measure a mile or so on their edges, and are tilted in various directions, leaving narrow rugged valleys between their upturned margins. The diverse tilting and the numerous fault scarps that rise without system into naked precipices combine to make this a region of the roughest and wildest description.
>
> The mountain mass forming the western border of Warner Valley below Crooks Bridge is bounded on the west also by a steep scarp that is probably the result of faulting. The fault scarp overlooking the Warner Valley is about 2,000 feet

high, and the opposite or western side of the block presents a face of equally grand proportions. The block thus defined is bounded in part by east-and-west faults and somewhat dissected by erosion. When viewed from a point a few miles to the northward it is seen to have a concave surface, and in fact forms a broad and extremely gentle synclinal. On its surface is a group of volcanic buttes of earlier date than the displacements that produced the dominant features in the present topography.

It is of interest to note that a faulting of considerable extent occurred in northern Nevada on October 2, 1915, causing three well-defined earthquake shocks, the last and most severe of which was distinctly felt in Warner Valley at about 11 p. m.

An article by H. P. Boardman [1] describing these earthquake shocks and the fault may be found in Engineering News of December 23, 1915. The fault is 24 to 30 miles long, and the throw ranges from a few inches to 15 feet at the place of greatest displacement. In one place a waterfall of 10 feet was created by the fault. Mr. Boardman was accompanied on his visit to Pleasant Valley, the scene of the faulting, by Prof. J. C. Jones, head of the department of geology at the University of Nevada.

The following is quoted from Mr. Boardman's article:

This remarkable fault is interpreted by Prof. Jones as confirming his ideas of the origin of most of the interior mountain ranges of Nevada; that is, that they were in the main caused by faulting. He states that this theory is concurred in by most geologists who have made a personal study of field geology in this locality.

The writer does not recollect having heard of another earthquake fault of such magnitude occurring so far inland (more than 350 miles), though such faults doubtless have occurred within historic times and certainly in geologically recent times. There are traditions that a severe earthquake occurred in this same region 40 or 50 years ago, and it may have been at that time that one of the old fault scarps still to be seen was formed.

A detailed description of the geological features of Lake County is given in a report by Gerald A. Waring,[2] who made a reconnoissance of the region in 1907. The following is quoted from Waring, omitting portions of his description not relating to Warner Valley and the surrounding table-lands:

Character and age of rocks.—In studying the geology of the region—the kinds of rocks and their structure—all of the consolidated materials that were seen are volcanic effusives and related volcanic muds, or tuffs. These rocks belong to several lithologic classes and to more than one geologic period, but by far the most extensive series is that of the basaltic flows. These cover nearly all of Lake County and extend eastward beyond Steins Mountain and northward beyond the John Day region, where fossils that have been collected from interbedded sedimentaries determine the age of the flows as Miocene.

No such fossil-bearing beds were found in the Lake County area, and the effusive material was not traced in detail to the place where such beds are

[1] Professor of civil engineering, University of Nevada.

[2] Gerald A. Waring. Geology and water resources of a portion of South-Central Oregon: U. S. Geological Survey Water Supply Paper 220, 1908.

exposed. But the material is so similar in lithologic character, in the amount of deformation it has undergone, and in its general relation to the Cascade Range to the west that there is little hesitation in placing it in the same general series with the widely extended and well-known Miocene lavas of Washington and northern-central Oregon. Although these Miocene basaltic lavas cover nearly all of the region examined with the exception of the lake valleys, there are sufficiently large areas of lavas of other types to warrant a preliminary separation into three groups—older acidic effusives, older basaltic effusives, and recent eruptive material. * * *

Classes of rocks.—The rocks of several mountain masses in this region differ enough from the more common basalts, both in the nature of the topography to which they give rise and in their petrologic character, to warrant us in considering them as belonging to an earlier period of more acidic effusion, when the lavas poured out were andesites, rhyolites, and related obsidians. They are, perhaps, of early Tertiary or pre-Tertiary age. In the succeeding effusions the materials were either basaltic or tuffaceous.

The Coyote Hills and Rabbit Hills masses are placed in the older class because they are composed largely of a light-colored glassy or porphyritic rock that seems to have been disturbed and eroded before being surrounded by the basaltic flows. These lavas are much more acid than the surrounding basalt, and they are regarded tentatively as rhyolites, andesites, and trachytes. * * *

Basalts.—The basalt of the main flows over the surface of the country is for the most part a dark-gray, fine-grained, rather vesicular rock, weathering on the more level areas into brown rounded cobbles and bowlders that make a very uneven surface, difficult to travel over.

On the higher peaks the more resistant types of this rock contain much iron and strongly affect the compass needle. Very little soil has formed over these high desert areas. Approximately parallel partings, usually at intervals of only a few feet, mark the division between successive flows, but in some places much thicker beds are exposed. Fissures nearly perpendicular to the parting planes break the basalt into blocks, which by transverse fracturing are reduced to smaller and smaller fragments, forming the characteristic talus slopes of the cliffs.

Tuffs.—* * * Interbedded with the basalts are thinner layers of tuff, or volcanic mud and ash. These are usually rather fine grained, white or red in color, and contain fragments of basaltic rocks. Where exposed along cliffs these tuff beds thin out, as if lenticular in shape, and in some instances serve to accentuate any unevenness in the associated basalt beds. * * *

Recent eruptive material.—In the northern part of the county is an area covered by sheets of lava and small volcanic cones or craters that represent a very recent period of volcanic eruption. Black vesicular basaltic rock constitutes the main part of the flow, while the cones are built up of slaglike fragments of scoria and volcanic bombs. This material clearly was ejected at a period much later than that of the great Miocene flows. It is probably Pleistocene in age.

The loose Pleistocene filling of the valleys and the alluvial material brought down by streams may be considered as a fourth class of surface material in this region.

Lake deposits.—No marine beds were seen, but some lake deposits should be mentioned here. * * *

In all of the lake valleys there are deposits of silts, sands, and clays that form the floor of the valley and usually bury any coarser material that may be in the basin. Remains of Pleistocene mammals fix the age of these deposits at Fossil Lake, in Christmas Lake Valley, where somewhat extensive collec-

tions have been made by representatives of the Smithsonian Institution, and in 1904 by a party from the University of California.

Alluvium.—Some alluvium is to be found where the several streams debouch into the open valleys, but in few places is the area thus covered of great extent. * * *

Honey Creek, in Warner Valley, has brought down and deposited on the valley edge a large amount of gravel.

Landslides and the slower weathering action that produces talus have also brought down much loose material from all the cliffs and steep slopes, but the areas covered by such material are not large.

Although in comparison with the great rocky basaltic areas these loose materials are geologically of minor importance, it is from them that practically all of the limited quantity of ground water now used is obtained. Hence from the viewpoint of the present water resources in the region this fourth class of unconsolidated material is perhaps the most important. The cultivable land is also limited to these areas of lake and stream deposits. * * *

WATER SUPPLY.

The following chapter on water supply has been prepared by Fred F. Henshaw, district engineer, United States Geological Survey, Portland, Oreg., for the Oregon cooperative work.

Discharge records.—The United States Geological Survey has obtained discharge records at 11 stations on streams in Warner Valley, and the Modoc County Irrigation Co. obtained records for short periods in 1913 at seven stations as well as a longer record on Twentymile Creek. Following is a list of gaging stations, giving length of records for each, and a tabulation of discharge records available:

Stations in Warner Valley, Oreg.

Station.	Records available for this report.
Twentymile Creek	Mar. 1, 1910–Sept. 30, 1915.
Twelvemile Creek (branch of Twentymile Creek)	May 14–June 30, 1912; Apr. 1–June 17, 1913; Feb. 1–July 5, 1914.
Deep Creek, at Big Valley	May 3, 1911–Sept. 30, 1915.
Deep Creek, at Adel	May 11, 1909–Sept. 30, 1915.
Camas Creek (above Mud Creek)	Apr. 25, 1911–Aug. 31, 1912.
Camas Creek (below Blue Creek)	Sept. 11, 1912–Sept. 30, 1914.
Mud Creek	Apr. 26, 1911–Aug. 31, 1912.
Honey Creek, at Chalstrand's ranch	Jan. 1–Dec. 31, 1911.
Honey Creek, near Plush	Jan. 1, 1910–Sept. 30, 1914; Mar. 3–May 16, 1915.
Twelvemile Creek (branch of Honey Creek)	Apr. 8–Dec. 31, 1911.
Snyder Creek	Jan. 1–Dec. 31, 1911.
Dismal Creek	Apr. 11–June 17, 1913.
Fifteenmile Creek, above Twelvemile Creek	Mar. 10–May 15, 1913.
Fifteenmile Creek, below Rock Creek	Mar. 7–May 12, 1913.
Rock Creek	Mar. 7–May 4, 1913.
Deep Creek, above Big Valley	May 1–June 17, 1913.
Crane Creek	Apr. 1–June 30, 1914.
Drake Creek	Mar. 18–May 10, 1915.

Monthly run-off, in acre-feet, of streams at border of Warner Valley.

	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Year.
1909–10.													
Twentymile Creek near Warner Lake	[1] 600	[1] 8,210	[1] 1,200	[1] 9,650	[1] 6,500	28,200	7,020	4,070	1,110	334	244	222	67,300
Deep Creek at Adel	978	21,100	6,640	14,800	2,430	49,600	25,500	15,200	3,150	601	518	893	141,000
Ditches diverting from Deep Creek	0	0	0	0	0	0	[1] 600	[1] 1,200	[2] 1,500	[1] 700	[1] 500	[1] 250	4,750
Honey Creek near Plush	[1] 600	[1] 8,210	[1] 1,200	9,650	6,500	16,400	9,700	4,220	600	111	[1] 92	[1] 89	57,300
Miscellaneous inflow	0	[1] 6,000	0	[1] 4,000	[1] 8,000	[1] 16,000	[1] 4,000	0	0	0	0	0	38,000
Total inflow to valley	2,180	43,500	9,040	38,100	23,400	110,000	46,800	24,700	6,260	1,750	1,350	1,450	308,000
1910–11.													
Twentymile Creek near Warner Lake	242	389	2,180	485	700	13,800	15,600	5,210	7,380	1,350	289	232	47,900
Deep Creek at Adel	1,070	2,510	9,590	2,950	2,720	18,300	27,100	27,400	25,300	3,390	676	690	122,000
Ditches diverting from Deep Creek	0	0	0	0	0	0	[1] 600	[1] 1,200	[1] 1,200	[2] 1,100	[1] 600	[1] 300	5,000
Honey Creek near Plush	161	4,540	6,400	[1] 430	[1] 222	16,500	7,910	9,530	7,740	394	333	118	54,300
Miscellaneous inflow	0	0	[1] 2,000	0	0	[1] 9,000	[1] 4,000	0	0	0	0	0	15,000
Total inflow to valley	1,470	7,440	20,200	3,860	3,640	57,600	55,200	43,300	41,600	6,230	1,900	1,340	244,000
1911–12.													
Twentymile Creek near Warner Lake	303	418	402	520	1,120	1,470	1,510	4,010	4,680	935	303	300	16,000
Deep Creek at Adel	732	1,260	1,190	1,590	5,680	4,700	15,900	55,000	35,100	3,090	830	280	125,000
Ditches diverting from Deep Creek	0	0	0	0	0	0	[1] 600	[1] 1,200	[1] 1,200	[1] 900	[1] 500	[1] 600	5,000
Honey Creek near Plush	162	260	328	[1] 430	[1] 403	652	1,930	9,780	3,670	812	584	458	19,500
Miscellaneous inflow	0	0	0	0	[1] 1,000	[1] 2,000	[1] 1,000	0	0	0	0	0	4,000
Total inflow to valley	1,200	1,940	1,920	2,540	8,200	8,820	20,900	70,000	44,600	5,740	2,220	1,640	170,000
1912–13.													
Twentymile Creek near Warner Lake	330	391	415	400	578	4,450	4,390	4,020	2,590	582	191	196	18,500
Deep Creek at Adel	1,000	3,250	1,450	1,730	1,740	7,130	33,500	35,800	15,200	7,070	928	845	110,000
Ditches diverting from Deep Creek	0	0	0	0	0	0	[1] 600	[1] 1,200	[2] 1,000	[1] 1,200	[1] 700	[1] 350	5,050
Honey Creek near Plush	400	649	[1] 984	[1] 307	471	1,340	5,010	7,930	3,040	1,160	[1] 184	[1] 119	21,600
Miscellaneous inflow	0	0	0	0	0	[1] 2,000	[1] 2,000	1,000	0	0	0	0	5,000
Total inflow to valley	1,730	4,290	2,850	2,440	2,790	14,900	45,500	49,000	21,800	10,000	2,000	1,510	160,000

[1] Estimated.

[2] Approximated from one measurement during month.

Monthly run-off, in acre-feet, of streams at border of Warner Valley—Continued.

	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Year.
1913–14.													
Twentymile Creek near Warner Lake	217	225	333	1,210	1,210	20,800	7,200	6,700	2,780	534	134	190	41,500
Deep Creek at Adel	1,420	2,080	984	6,700	2,320	30,000	32,400	22,900	9,460	1,830	324	417	111,000
Ditches diverting from Deep Creek	0	0	0	0	0	0	131	1,120	988	578	[1] 922	[1] 774	4,510
Honey Creek near Plush	[1] 184	253	390	1,140	1,060	7,990	7,620	5,570	2,370	459	[1] 92	[1] 60	27,200
Miscellaneous inflow	0	0	0	0	[1] 2,400	[1] 9,200	[1] 3,000	0	0	0	0	0	14,600
Total inflow to valley	1,820	2,560	1,710	9,050	6,990	68,000	50,400	36,300	15,600	3,400	1,470	1,440	199,000
1914–15.													
Twentymile Creek near Warner Lake	286	291	371	439	482	4,880	2,990	5,910	2,240	366	136	161	18,600
Deep Creek at Adel	1,110	1,190	[1] 1,230	[1] 1,540	1,180	6,950	14,100	17,800	[1] 7,910	1,090	218	[1] 298	54,600
Ditches diverting from Deep Creek	0	0	0	0	0	0	384	1,600	1,610	701	[1] 621	[1] 506	5,420
Honey Creek near Plush	[1] 184	[1] 238	[1] 184	[1] 246	[1] 444	873	3,310	3,400	[1] 1,190	[1] 396	[1] 123	[1] 119	10,700
Miscellaneous inflow	0	0	0	0	0	[1] 500	[1] 800	[1] 1,000	0	0	0	0	3,300
Total inflow to valley	1,580	1,720	1,780	2,220	2,110	13,200	22,600	29,700	13,000	2,530	1,100	1,080	92,600

[1] Estimated.

Monthly run-off, in acre-feet, at headwaters of streams of Warner Valley.

	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Year.
1910–11.													
Deep Creek at outlet of Big Valley	....	....	....	....	....	....	....	15,500	23,100	3,300	[1] 615	678	....
Camas Creek above Mud Creek	....	....	....	....	....	....	....	5,950	1,510				
Mud Creek near Plush	....	....	....	....	....	....	....	5,630	3,000	....	....	....	....
Honey Creek at Charlstrand's	[2] 455	[2] 482	[2] 369	[1] 370	[1] 167	2,660	3,650	5,320	2,990	497	219	238	17,500
Twelvemile Creek near Plush	[2] 47	[2] 78	[2] 72	[1] 100	[1] 100	[1] 3,000	1,100	1,660	2,740	196	32	42	9,170
1911–12.													
Deep Creek at outlet of Big Valley	1,120	1,100	[1] 615	[1] 689	1,400	[1] 1,190	4,110	21,200	16,900	1,730	572	565	51,200
Camas Creek above Mud Creek	....	....	....	1,190	1,050	1,400	4,390	8,980	2,210	273	95.3	....	[3] 19,600
Mud Creek near Plush	....	....	....	392	563	408	1,110	6,700	2,210	541	280	....	[3] 12,200
1912–13.													
Deep Creek at outlet of Big Valley	566	553	[1] 492	[1] 492	551	2,200	10,400	19,900	8,750	2,880	682	391	47,900
Camas Creek below Blue Creek	418	1,030	[1] 369	[1] 369	544	1,560	9,820	9,350	2,340	1,300	400	196	27,700
1913–14.													
Deep Creek at outlet of Big Valley	499	666	430	2,070	833	9,100	17,000	16,900	6,960	1,240	498	490	56,700
Camas Creek below Blue Creek	369	559	416	[1] 1,720	[1] 555	9,650	13,100	6,890	2,600	682	450	430	37,400
Crane Creek below Crane Lake	[1] 50	[1] 50	[1] 50	[1] 50	[1] 50	[1] 1,200	1,370	190	367	[1] 50	[1] 50	[1] 50	3,530
1914–15.													
Deep Creek at outlet of Big Valley	658	461	[1] 369	[1] 492	[1] 444	[1] 2,710	7,680	12,100	6,010	873	298	[1] 196	32,300
Mud Creek near Plush	....	....	....	....	....	[4] 114	2,580	[5] 694	....	....	....	....	[6] 6,500
Drake Creek near Adel	....	....	....	....	....	[7] 1,100	1,370	[8] 290	....	....	....	....	[6] 5,800

[1] Estimated.
[2] October, November, and December, 1911.
[3] Total for period.
[4] Mar. 27–31.
[5] May 1 to 9.
[6] Estimated total for year.
[7] Mar. 18–31.
[8] May 1–10.

Monthly run-off, in acre-feet, of Twentymile Creek and tributaries, 1913.

	March 7-31.	April.	May.	May 1-12.	June 1-17.
Fifteenmile Creek above Twelvemile Creek	328	591	328	176	....
Twelvemile Creek	(250)	672	4,020	810	1,660
Keno Creek	506	282	0	0	....
Rock Creek	2,220	2,230	6	6	....
Total	3,300	3,780	4,350	992	1,660
Fifteenmile Creek below Rock Creek	4,450	4,240	....	876	....
West Fork Horse Creek	475	137	....	0	....
East Fork Horse Creek	146	58	....	0	....
Total	5,070	4,440	....	876	....
Twentymile Creek near Warner Lake	3,760	4,200	....	1,050	1,880

Unmeasured inflow.—As practically all water entering Warner Valley above the Campbell Lakes can be collected and used by pumping, an estimate of the unmeasured inflow is desirable.

The subject was not studied until 1912, and data obtained indicated that the inflow was small both in that year and in 1913. Conditions were such that most of the snow on the lower areas sank into the ground as it melted.

Provisional estimates of miscellaneous inflow to Warner Valley in 1914 give the following results:

	Acre-feet.
Rabbit Creek	1,000
Fish Creek, near Plush	3,700
Big Lake	3,500
Tributaries of Coleman Valley	1,000
Greaser Canyon	400
West slope of Hart Mountain and slopes between Plush and Adel	5,000
Total	14,600

The flow was estimated by Stewart in the field, except that for Fish Creek, most of which was measured, and Hart Mountain run-off, which was estimated afterwards.

Inflow from miscellaneous sources in 1915 was estimated as follows:

	Acre-feet.
Rabbit Creek	Practically none.
Fish Creek, computed from rise of water surface in reservoir	300
Big Lake	500
Tributaries of Coleman Valley	300
West slope of Hart Mountain and slopes between Plush and Adel	2,000
Total	3,300

The preceding tables of run-off include a roughly approximate estimate of the run-off from these sources from 1910 to 1915. The year 1910 was favorable to a heavy run-off from low-level areas, as the snowfall was heavy and went off quickly early in the spring.

Conditions in 1911 were less favorable to a heavy yield, although it was a good water year. The next two seasons were years of light snowfall, most of the water from which was absorbed by the ground.

Only a part of this miscellaneous run-off can be used for proposed irrigation systems. The flow of Rabbit Creek, Fish Creek, Greaser Canyon, and the tributaries of Coleman Valley is already completely utilized in a year of low flow. Most of the streams flowing from Hart Mountain are also diverted onto ranch lands near the edge of the valley. The inflow to Big Lake could be recovered for use in the valley only by pumping it out of the basin in which it collects over a rim at least 30 feet high, and the yield is probably too irregular to warrant the expense.

Accuracy of stream-flow estimates.—Warner Valley is difficult of access, particularly the headwaters of the streams, and as funds have been insufficient to provide proper equipment of the stations many of the records are not as precise as could be desired.

The station on Twentymile Creek, near Warner Lake post office, is one of the best in the valley. Its control is a permanent rock reef, and the datum of the gage has been fairly well maintained. The discharge prior to March, 1914, has been computed from one or two gage readings daily. In the spring there is a large diurnal fluctuation, sometimes a foot or more, due to the rapid melting of the snow in the daytime, and even two readings daily may not give the true mean closely. Records during March and April, 1910, were taken from a gage which was at times affected by backwater from an irrigation dam below. A conservatively low estimate has been made for October, 1909, to February, 1910. The total yield of the large low-level area tributary to Twentymile Creek may be greater than the accepted estimate.

The station on Deep Creek at Big Valley has seldom given altogether satisfactory results. It is difficult of access; and although a water-stage recorder has been used except in 1911, gaps in the record of stage are numerous. The flood records are generally the best, and the total run-off for the year can usually be estimated closely.

The station on Deep Creek at Adel is fairly good. The control is practically permanent, diurnal fluctuation is not great, and conditions at the measuring section are favorable. Flood records are good, and the estimates of total yearly run-off are little affected by the poor results occasionally obtained at low stages and in the winter. Considerable water is diverted immediately above the station for irrigation, but the quantity is only 5 to 10 per cent of the total run-off, and good records are available for the last two years.

Records on Camas Creek are only fair, except for high water of 1914, for which they are excellent.

The station on Honey Creek near Plush has been unsatisfactory much of the time. The gage readings for high water represent only approximately the daily mean previous to 1912, on account of the great diurnal fluctuation and lack of a water-stage recorder. The channel has been unstable and conditions for making measurements are not the best. The records for the last three years are, however, reasonably good. A rough estimate of the flood run-off of November, 1909, and January, 1910, has been made in order to complete the years' records. The published records of discharge of the tributaries of Honey Creek are fair.

A gage on Snyder Creek was read during 1911, but no high-stage measurements were made. An approximate estimate made by extending the rating curve indicates that the total run-off for the year was between 6,000 and 7,000 acre-feet. The total run-off for 1915 up to April 15 was stored in the reservoir and about 600 acre-feet accumulated. The run-off had almost ceased by that time, but probably more resulted from the rains in the last part of April and about May 10. The total run-off for the year may have been 750 acre-feet. It must have been heavy in 1910, probably over 10,000 acre-feet; in 1911–12 and 1912–13 the yield may have been as low as two or three hundred acre-feet.

Evaporation.—Observations of evaporation from standard pans have not been made in Warner Valley, but records of the rate of fall of the Flagstaff lakes, obtained in 1915, are perhaps of even greater value than pan records would be in estimating the probable evaporation from lakes or reservoirs on the floor of the valley.

The four bodies of water frequently shown on maps as Flagstaff lakes contained water throughout the season, but were cut off from any inflow from Hart Lake, practically the only water reaching them being from precipitation. From March 23 to May 3 Flagstaff Lake fell 0.28 feet, Lower Campbell 0.33 feet, and Stone Corral Lake 0.28 feet, a mean of 0.30 feet. Adding 0.14 feet, the estimated precipitation, gives 0.44 feet as the total evaporation in 40 days, or at the rate of 0.33 feet per month. Flagstaff Lake fell 2.45 feet from March 23 to September 28, Lower Campbell 2.53 feet from March 21 to October 5, and Stone Corral Lake 2.41 feet from March 23 to October 5, or an average for 6 months and 11 days of 2.46 feet.

To make these figures applicable to a normal year, at least 0.20 foot must be added as allowance for the fact that the average temperature was below normal in southern Oregon from April 1 to September 30, 1915. The deficiency at Lakeview for this period, 2° F., has been assumed to apply to the Flagstaff Lake region. To obtain the gross evaporation the estimated rainfall, 0.35 foot, must be added, making the total 3.06 feet.

As these estimates agree very closely with those used in the power report on Deschutes River[1]—0.30 foot for April, 3 feet April to September, inclusive, and 3.90 feet for the year—they have been accepted for this report. The gross evaporation for Big Valley Reservoir or any of the other reservoirs similarly situated in the mountains several hundred feet above the valley would probably be less—say, possibly as little as 3 feet per year.

Precipitation.—The longest record of precipitation available in Warner Valley was obtained at Camp Warner, the old Army post on the slopes of Hart Mountain. The mean for the five years 1869 to 1874 was 14.80 inches, the maximum yearly total being 17.67 inches in 1872, and the minimum 11.79 inches in 1870.

Rainfall records are available for only two short periods in recent years—February to September, 1910, at Plush, and March to July, 1914, at Adel. The total for the first period was 4.13 inches, the greatest for any month being 1.07 inches for May. During the same period the total for Christmas Lake was 4.63 inches, for Burns 5.29 inches. The normal yearly total for Burns is 10.58 inches. If the ratio was the same as in 1910, the mean yearly precipitation for Plush would be 8.3 inches. A similar comparison with records obtained at Christmas Lake gives 7.6 inches for Plush. Comparisons with records at Burns and Lakeview for 1914 indicate that mean yearly precipitation for Adel is probably 9 to 10 inches.

From the topography and the appearance of the vegetation it is believed that the average annual precipitation in the southern end of Warner Valley proper is 9 or 10 inches; in north Warner Valley around Bluejoint Lake it is probably only 6 or 7 inches, but for a small area under the steep slopes of Hart Mountain it may be 12 to 15 inches.

Fluctuations of the Warner lakes.—The Warner lakes afford exceptionally favorable conditions for securing information as to past climatic changes. With increasing aridity at least five of the large lakes—Bluejoint, Stone Corral, Lower Campbell, Upper Campbell, and Flagstaff—dry up successively in the order named. In 1914 J. E. Stewart, of the United States Geological Survey, made extensive inquiries as to the history of their fluctuations since the settlement of the valley, and especially as to their drying up, believing the fact that a certain lake dried up in or about a given year would be more readily noted and remembered than the stage of a fluctuating lake.

From 1876 to 1884 the run-off was large except in two or three years. About 1885 a series of dry years began, culminating in 1889, which was a year of such exceptional dryness as has probably not

[1] Henshaw and others. Deschutes River and its utilization: United States Geological Survey Water Supply Paper No. 344, pp. 86–88.

been duplicated in the last half century. Bluejoint, Flagstaff, and intervening lakes had no doubt gone dry before this. In the fall of 1889 all that was left of Crump Lake was a comparatively small area on its west margin. The shallow parts of Hart Lake were dry, and teams were driven across the lake bed from the east side of the valley to Plush. The total inflow to the valley in 1889 must have been considerably less than in 1915; 70,000 acre-feet seems a reasonable estimate.

The year 1890 was one of heavy snowfall and run-off, and the lakes were probably well filled up in one season. The only record of the height of this flood is a high-water mark preserved on a blacksmith shop beside Honey Creek at Plush. From this the maximum discharge of the creek was estimated at 3,500 to 4,000 second-feet, or about 50 per cent greater than the maximum in 1910. The early nineties were probably wet, and about 1895 the lakes reached a high level.

In 1898 another series of dry years began, which lasted until 1903, when Bluejoint, Stone Corral, and Lower Campbell lakes were dry, and probably Upper Campbell. The year 1904 was very wet generally in eastern Oregon; 1905 and 1906 were again relatively dry, and Bluejoint Lake dried up; 1907 and 1909 were wet, and the lakes were probably nearly as high as in 1910, when records of stage were begun.

For the period prior to 1880 very little data could be obtained. Col. John C. Frémont spent about three days in Warner Valley in December, 1843. From his description there was evidently some water in all the lakes, including Bluejoint. He recorded the impression that at times of high stream flow there was an abundance of water, but stated that he found scarcely more than the dry beds. This may be explained by assuming that the lakes were at their lowest stage for the year.

It is reported that in the late sixties several hundred acres near the northern end of the valley were overgrown with tules. Practically no tules are now found north of Flagstaff Lake, and the water must have been high for some years and recently freshened by a heavy inflow for them to have secured a foothold.

The soldiers coming into Warner Valley to establish Camp Warner are said to have had considerable trouble in avoiding the swamps north and west of Bluejoint Lake.

A very distinct beach line that appears to have been formed by a high stage of the lake within a century extends entirely around the north end of Warner Valley. Sagebrush has become established under it, but none of the bushes are over 30 or 40 years old. It is possible that this marks a stage reached in the late sixties, when high water

was general throughout the Great Basin. Mr. A. H. Hammersley, of Lakeview, states that at the time his father came to Lake County in 1869 the Warner lakes were very high, and he believes that this beach line was formed at that time.

Considerable information in regard to the fluctuation of the lakes in south-central Oregon was collected by I. C. Russell during his trip through this region in 1882. Prof. Russell's report[1] states:

One of the most interesting of the recent changes in the extent of the lakes in the region embraced in our reconnoissance is the union of Harney and Malheur Lakes. Previous to a season of unusual humidity about the year 1877 these lakes were separated by an embankment of gravel—probably a bar built by the waves and currents when the water was deeper than at present—which was breached during the season of high water, causing the lakes to be united. The present combined water surface retains the name of Malheur Lake.

Persons who have been familiar with Silver Lake (Lake County) since 1870 have never known it to become dry; its present freshness, however, would indicate that such an occurrence took place not many years since, as inclosed lakes are supposed to be freshened by desiccation. During the past three years its waters have risen about 6 feet and flooded large areas that previous to 1879 were meadowlands and pastures. Owing to this recent rise Thorn and Silver Lakes are now confluent. The difference between the winter and summer horizons of the lake's surface is about 2 feet.

Goose Lake has not overflowed, except during a single storm, since 1869. For a term of years prior to that date its waters were much lower than at present, as is shown by the fact that a road then crossed the lake basin some 4 or 5 miles from its southern end at a place which is now covered by 15 feet of water. During the past few years it has been rising, and in 1881 it is reported to have overflowed for two hours or more during a severe gale from the north.

Horse Lake is a small playa lake situated in the eastern border of California between Honey Lake Valley and the Madeline Plains. Its ancient channel of overflow is carved through a volcanic mesa and joins Snowstorm Canyon. In 1868 the lake rose sufficiently to overflow and send some tribute to Honey Lake through its long-abandoned channel. The bottom of the outlet is about 10 feet above the usual level of the lake, showing that the high water of 1868 was considerably more than the ordinary winter's rise. The lake became dry in the summers of 1878 and 1879, its bottom forming a hard, smooth mud plain.

The history of Silver Lake since Russell's report was written is interesting in this connection: It became dry in 1889, but was filled in 1890, as was also Thorn Lake, and some water overflowed into the Christmas Lake Valley; in 1904 it again overflowed.[2] No observations were made of its height after 1905 until 1912, when it had fallen about 5 feet below its high-water mark. In October, 1915, it had fallen 4.2 feet more, and its greatest depth was only about 4 feet.

[1] Russell, I. C. Geological Reconnoissance of Southern Oregon; U. S. Geological Survey Fourth Annual Report, pp. 435–464, 1883.

[2] See Silver Lake Project Report, 1915, Oregon cooperative work.

The fluctuations of the Warner Lakes as deduced from the evidence at hand is shown in the following diagram, which shows the volume of storage at the maximum stage for each year:

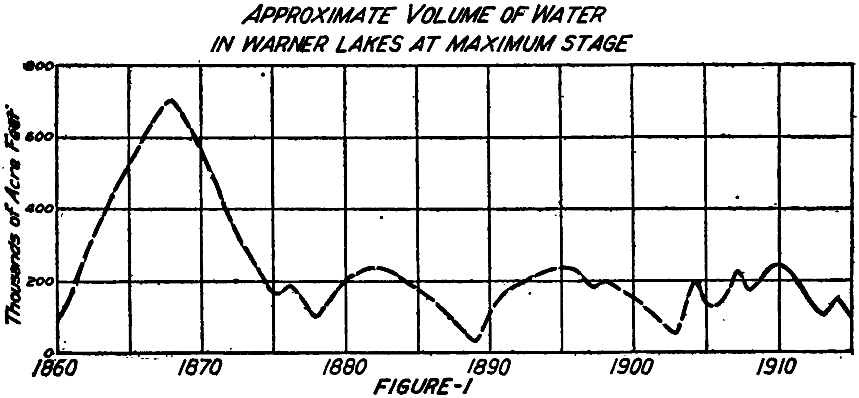


FIG. 1.—Appropriate volume of water in Warner Lakes at maximum stage.

Vertical distances represent quantities of water accumulated in the lakes, which would be greatest at the end of a series of high years and not necessarily in the year of greatest run-off. A falling line indicates a year or series of years drier than the normal. The scale is only relative, but three conditions are represented by horizontal lines. The highest represents the highest stage reached by the lakes in 1910; the next indicates the point at which Bluejoint goes dry or at which water begins to flow into it on a rising stage; the lowest represents the condition at which all the lakes would be completely dried up.

Three general but important conclusions may be drawn from the data at hand in regard to the fluctuations of the lakes:

1. The period 1910–1915, for which records are available, has been drier than the normal, as is shown by the falling stage of the lakes.

2. There have been periods marked by an even more severe shortage than the last six years; in fact, there have probably been periods of six or seven years when the available inflow to the valley was no greater than for the four years 1912 to 1915, inclusive.

3. There have been periods of a number of years each when the inflow was so great that a very large volume of water must have accumulated in the north end of the valley. Such periods are likely to recur.

Quaternary Lake Warner.—The evidences of the existence of a former large lake in Warner Valley have been discussed by Van Winkle[1] from investigations made in the fall of 1912.

[1] Van Winkle, Walton. Quality of Surface Waters of Oregon; U. S. Geological Survey Water Supply Paper 363, p. 110, 1914.

Shore lines of a large, deep lake that occupied the valley within Quaternary times are discernible at several places along the cliffs, and one strongly defined beach 268 feet above the present water surface can be traced for miles. The strong definition of this beach is evidence that the lake was stationary at one level for a long time. It is apparently the current belief that the Quaternary Warner Lake had no outlet, for Russell,[1] after a reconnoissance of the Great Basin in southern Oregon, stated that only the lakes occupying the Harney, Goose, and Klamath Basins in Oregon and the Madeline Plains in California had outlets, and his statement apparently was accepted by Waring.[2] Free[3] also has concluded that the Warner Basin has always been entirely inclosed. The writer's investigations have, however, led him to believe that the lake had an outlet.

The rim of its basin north of Warner Lake is relatively low,[4] a gentle slope rising northward and attaining a maximum elevation of about 190 feet above the present level of Bluejoint Lake about 12 miles north of the lake. The top of the divide there appears to have been formed by deposits from a stream that flowed in a canyon opening from the west. Just north of the divide Mule Spring discharges into a rivulet which flows northward in a wide, shallow valley 25 feet lower than the divide and finally sinks into the desert. Approximately a mile beyond Mule Spring is another divide, perhaps 25 feet higher than the more southerly one, and also formed apparently by alluvial deposits.[5] A basin north of this second divide, probably a continuation of the valley of the Mule Spring Creek, also terminates on the north in a divide with another basin beyond. Thus there are three basins separated by low divides. The floors of the basins are less than 4,700 feet above sea level and slope northward. Beyond the northernmost divide a canyon, which winds away to the northwest, opens into Big Stick Canyon, which in turn circles around Iron Mountain and enters Harney Basin from the west.

However, J. E. Stewart discovered a basaltic dike lying across the apparent outlet canyon and extending 70 to 80 feet above the level of the ancient beach. The surface of the dike is water-worn. It is possible that there has been local faulting or tilting since Quaternary time, which has raised the outlet relative to the southern end of the valley.

Van Winkle further states:[6]

The probability of the existence of an outlet to the Quaternary lake can also be roughly determined by considering the relation of its water surface to the area of its drainage basin. If a lake has no outlet its water level will rise until evaporation from the surface counterbalances the additions by rainfall and inflow. At that stage there will be for a given set of conditions a definite ratio between the area of the lake surface and that of the tributary basin,

[1] Russell, I. C., op. cit., p. 458.

[2] Waring, G. A. Geology and Water Resources of the Harney Basin Region, Oreg.; U. S. Geological Survey Water Supply Paper 231, 1909.

[3] Free, E. E. The Topographic Features of the Desert Basins of the United States with Reference to the Possible Occurrence of Potash; U. S. Department of Agriculture Bulletin 54, pp. 26, 60, 1914.

[4] Description and elevations based on notes by Garfield Stubblefield, civil engineer, Portland, and on unpublished surveys by the Oregon Eastern Railway.

[5] The railroad surveys of the Oregon Eastern Railway do not follow the canyon closely at all places, and the elevations as shown by the railroad surveys are somewhat greater than those mentioned.

[6] Van Winkle, Walton, op. cit., p. 111.

which will be the same for all basins exposed to similar conditions. Russell placed the ratio of the surface of Lake Lahontan to its total drainage area at approximately 1 to 5. No topographic maps have been made which will furnish exact information regarding the extent of Quaternary Warner Lake and its basin, but the best available maps indicate that the ratio of its water surface to its drainage area was about 1 to 5. If this ratio is correct and if Warner Lake had no outlet the early Quaternary precipitation in Warner Basin must have been almost exactly equal to that in Lahontan Basin. But as the precipitation in Warner Basin is now one-third greater than in Lahontan Basin and as no known physiographic changes since early Quaternary time would have made a great alteration in relative precipitation, it is probable that precipitation then was greater in Warner Basin than in Lahontan Basin. On this assumption, Warner Lake must either have had an outlet or must have filled its basin to a level several hundred feet higher than the highest beach—an obvious improbability.

Briefly, the available physical evidence points to the possibility that the ancient Warner Lake discharged northward; confirmation of this evidence might be obtained by determining whether the low divides of the basin are composed of alluvial material or bedrock and also whether the surface has been locally distorted since early Quaternary time.

If Warner Lake overflowed in early Quaternary time its water was then fresh, and consequently salt deposits that may now occupy the former lake bed have been formed by concentration only of the material that has been washed into the lake bottom since the lake ceased to have an outlet. The small size of the former lake and the presumably low concentration of its water make it entirely unlikely that saline deposits of great thickness or extent now underlie the surface, and this relatively small amount of saline material is probably mixed with much greater quantities of clay and silt. Several wells that have been sunk in the valley are said to have penetrated strata of strongly alkaline and probably borated salts mingled with silt and sand, a condition that renders unlikely the existence of extensive valuable saline deposits. Rock salt of low grade has been obtained for years by solar evaporation of brines obtained presumably from the strata just below the surface at the north end of the valley, but this deposit is probably local and the product is economically unimportant, being used chiefly for salting stock. The salt is somewhat carbonated but contains only a small amount of sulphate.

South-central Oregon is celebrated for its enormous springs, many of which form veritable rivers. Portions of the upper Deschutes River, Spring River, Metolius River, and Crooked River, tributary to Deschutes River, and Ana River, tributary to Summer Lake, are noteworthy examples of spring-fed streams. These underground waters must travel great distances through the porous and faulted lava of this region, and the Quaternary Lake in Warner Valley may have been maintained at its upper level by underground drainage.

WELLS AND DOMESTIC SUPPLY.

The streams entering Warner Valley—Twentymile, Deep, and Honey Creeks—where they reach the valley floor have built up alluvial fans many thousands of acres in extent. The deposits thus made are water bearing, and wells of moderate depth secure an

abundance of good water for domestic use. Near the lower limit of these deposits cased wells extending a few feet above ground produce a small running stream of water which is used to supply watering troughs for the many thousands of cattle pastured on the marsh lands. Numerous springs rise in the gullies eroded from the valley walls, and the talus material below these springs is a source of supply for good water, the springs themselves often being the direct supply for a near-by ranch.

But few wells have been dug in the valley bottom proper, and little is known of the character of this ground water supply. One well at the Bluejoint ranch west of Bluejoint Lake supplies water which, while alkaline to the taste, is fit for domestic use, and many horses are watered at this well, which is operated by windmill and gasoline-engine pump.

Many warm springs issue from the foot of the steep slopes along the western border of South Warner Valley. The great number of these may be noted when driving along the road from Adel to Plush on a cold morning by the cloud of vapor rising from each spring. The flow of these springs is small, however, and not to be considered as a supply for irrigation.

EARLY INVESTIGATIONS AND SURVEYS.

United States Geological Survey, Waring, 1908.—During the season of 1907, Gerald A. Waring conducted a reconnoissance survey of the greater part of Lake County, which includes nearly all of Warner Valley and tributary area included in this report. The results of his investigation are embodied in a report published in 1908.[1] Copies of this report are now difficult to obtain, and many quotations from it are therefore included herein, especially information relating to geology. Topography sketched by Waring throughout the tablelands adjacent to Warner Valley has been of much value in filling out the general topographic map in this report.

If possible to obtain Waring's report, it should be read in conjunction with this report.

Warner Lake Irrigation Co., 1909–1913.—In 1909 the Warner Lake Irrigation Co. began investigations in North Warner Valley, with the object of irrigating Government lands lying in the Rabbit Creek Basin and in the valley bottom proper not occupied by the lakes. A segregation of 118,000 acres under the Carey Act was made. The plan proposed at that time was to store the waters of Honey Creek and conduct these waters by gravity canal to the lands mentioned. Surveys were made of the Snyder Creek and Honey Creek Reservoir sites. (See Plate No. 1.)

[1] Gerald A. Waring. U. S. Geological Survey Water Supply Paper 220; Geology and Water Resources of a portion of South-Central Oregon, 1908.

It was soon realized that the water supply thus developed would be wholly inadequate for the land proposed to be irrigated. Attention was then turned to securing a supply from streams entering South Warner Valley. The Deep Creek drainage basin was first investigated, and an excellent reservoir site found at Big Valley. A survey of this site was made on a scale of 1,000 feet to the inch. It was proposed to divert Deep Creek about 3 miles above the falls and conduct the water by gravity canal down the Deep Creek Canyon and follow the rim rock of the west side of the valley northward to lands in the north end of the valley. A transit and level line survey was made for this canal line about 750 feet above the floor of the valley. This canal throughout the greater part of the distance from Deep Creek to Honey Creek would be along the steep, rocky cliffs, generally above the talus slope, and would involve expensive excavation in rock or bench flume.

In 1910 a reconnoissance was made to determine if waters stored in Big Valley could be conducted across the table-lands west of the rim rock, but it was found by later survey to be impracticable on account of both the great length of canal required and the character of construction involved. Two tunnels would be necessary, one about 3,000 feet long and one about 6 miles long, the latter through the highest parts of the divide between the headwaters of Drake Creek, a tributary of Deep Creek, and Twelvemile Creek, a tributary of Honey Creek. These two surveys brought out the impracticability of conducting the stored waters of Deep Creek to lands in the north end of the valley by gravity canals. In conducting these surveys about 135 miles of canal line were run in addition to surveys of the various reservoir sites. For additional storage in Deep Creek watershed a preliminary survey was made of the upper basin on Camas Creek, above the junction of Mud Creek with that stream.

At the close of the season of 1910 the plan developed into a scheme for storage of the waters of Deep and Camas Creeks, and development of power on Lower Deep Creek for pumping from Hart Lake and Flagstaff Lake to canals for irrigating the lands in North Warner Valley. It was proposed to build a low dike across South Warner Valley about a mile south of Pelican Lake, and a similar dike, with controlling gates, near the Stone Bridge, thus forming a reservoir of that portion of the valley between the dikes. It was also proposed to reclaim that portion of the valley south of this reservoir by pumping the drainage waters over the dike into the proposed reservoir.

These plans required two pumping plants in South Warner Valley, one to pump drainage waters from the 28,000 acres to be reclaimed south of the reservoir heretofore referred to, and one in the Coleman Valley outlet to pump excess waters from a canal to be

dredged into Coleman Valley to a higher canal to serve lands in both Coleman Valley and the east side of South Warner Valley. In this scheme the lower portion of Coleman Valley would act as a storage reservoir for these lands, from which the water would be pumped in the latter part of the irrigating season.

In North Warner Valley dredged channels were to connect the chain of lakes. Controlling gates were to be provided at the outlet of each. A low-line canal from the Stone Bridge controlling gates was to lead around the west side of Hart Lake about 5 feet above its normal elevation, to serve all of the valley lands lying below the canal. A pumping plant about 3 miles west of Mugwump Lake was to lift water from this canal to serve the higher sloping lands in the vicinity and north of Plush to the pumping station.

Two pumping stations were planned in the extreme north end of the valley to pump from the low canal to serve lands lying above the canal to the west and north of Bluejoint Lake. The plant, located near the northwest end of Flagstaff Lake, was to pump to a high-line canal from a feed canal leading from Mugwump Lake and skirting the west side of Flagstaff Lake. This high-line canal was to serve the lands in the Rabbit Creek Basin. This lift as planned is about 120 feet. In order to reduce the evaporating area as much as possible, it was planned to pump from Flagstaff Lake in the early part of the season, when this lake might have water in it as a result of overflow from Hart Lake. Thereafter water was to be brought through the Bypass Canal from Mugwump Lake to the pumping plant.

The area proposed to irrigate in North Warner Valley under this plan was 90,000 acres, or a total development in the whole valley of 118,000 acres. The probable cost of the development plans outlined, together with Big Valley storage and power development on Lower Deep Creek, requiring a 75-foot diversion dam just above Deep Creek Falls, 2½ miles of concrete-lined power canal, power house, penstocks, and power equipment, was found to be $3,956,000, or about $33.50 per acre, ranging in the different units from $28 to $36 per acre.

The investigations of 1911, 1912, and 1913 were confined chiefly to securing stream-flow data and to making surveys suggested by the development outlined above. This work in the field was done by John Dubuis for the Warner Lake Irrigation Co. An accurate survey and soundings were made of Hart Lake, and control lines run between the various lakes to determine relative elevations. A transit line was also run from the "Stone Bridge" entirely around South Warner Valley, including Coleman Valley, at an elevation of about 50 feet above the valley bottom. A line at this same elevation was run around the west side and north end of North Warner

Valley to Bluejoint Lake, and detail topography taken of approximately 3 square miles northwest of Flagstaff Lake for the purposes of detailed estimates in connection with the pumping plant to serve Rabbit Creek Basin.

A transit line was also run around the Rabbit Creek Basin at the 120-foot elevation above Flagstaff Lake in order to delimit the land which could be served by the pumping plant. Level and transit lines were run up Honey Creek from near Plush to the Snyder and Honey Creek Reservoir sites, and a branch line of Twelvemile Creek as far as McDowell Creek. Considerable topography was taken in Lower Deep Creek Canyon to determine the best location for a power canal. An accurate survey was also made of the Mud-Camas Reservoir site on a scale of 1 inch to 400 feet, this reservoir site being considered in connection with additional power development on lower Camas Creek. This development was expected to provide 7,000 horsepower for commercial use, at a 50 per cent load factor.

A topography line was extended up Deep Creek Canyon to Big Valley Reservoir site for the purpose of determining the relative elevation and additional power possibilities on that stream above the development already planned on Lower Deep Creek. The datum assumed for the 1911–1913 surveys of the Warner Lake Irrigation Co. was that of Waring in 1907, based on aneroid barometer elevations carried from Lakeview, the nearest point from which sea-level datum could be obtained. Waring shows the elevation of Hart Lake to be 4,544 feet on his general topographic map in Water Supply Paper 220, heretofore referred to.

Two hundred and sixty miles of transit and topography lines were run in connection with the 1911–1913 work, in addition to detail surveys of the Mud-Camas Reservoir site, soundings of Hart Lake covering about 6 square miles, and the 3 square miles of detail topography taken in sections 23 and 24 and the north half of sections 25 and 26, T. 34 S., R. 24 E. Practically all of the notes taken in the course of the various surveys made by the Warner Lake Irrigation Co. were platted, and have been used in this investigation for making up the general topographic map.

INVESTIGATIONS FOR THIS REPORT.

Field investigations for this report were made in September and October, 1915, and consisted in examining the various reservoir sites and in securing topography in the valley bottom, to supplement the surveys made by the Warner Lake Irrigation Co.

W. R. Parkhill conducted the field work, assisted by two rodmen in taking plane table topography.

The work in North Warner Valley consisted of determining the limits of Anderson, Mugwump, and Flagstaff Lakes. Detail topog-

raphy was taken of the inlet to Hart Lake from the Stone Bridge south for about a half mile, on a scale of 1 inch to 400 feet. The purpose of this was to develop more fully the storage possibilities in conformity with the plan of making a reservoir of the Crump Lake region of South Warner Valley, as outlined under "Early investigations and surveys."

In South Warner Valley topography was taken of about 40 square miles of the swamp area and a survey made of Crump Lake. This topography was taken to determine the possibility of draining the rich, peaty lands of this part of the valley now covered with tules and flags, as the surveys of the Warner Lake Irrigation Co. did not cover the valley bottom and the topography of such areas shown on their maps was sketched.

RESERVOIR SITES.

No detail surveys were made of reservoir sites with the exception of the lowest portion of Coleman Valley, which may be used either as a reservoir or as a sump for disposing of water in years of excessive run-off. Each reservoir site, however, was seen by Mr. Parkhill, the character of lands in it was noted, and the dam site was examined.

COLEMAN VALLEY.

Coleman Valley is a southerly extension of Warner Valley and connected to it by a long, narrow outlet varying in width from about a quarter of a mile to a mile. (See Plate No. 1.) The general elevation of this outlet is about the same as that of the valley floor, while the deeper part of Coleman Valley is about 21 feet lower. The capacity of the valley at the outlet elevation is about 60,000 acre-feet. By dredging a channel 10 feet deep from the main drainage channel through Warner Valley to Coleman Valley, with controlling gates for the depth of this dredged channel, 60,000 acre-feet of water could be run into the reservoir during the early spring run-off, and 30,000 acre-feet of this amount could be drawn back during the irrigating season through the same drainage channel to supply the lakes in North Warner Valley in the irrigating season. The inflow could be diverted from Deep Creek and carried across the valley bottom over the main drainage channel and discharge into the Coleman Valley outlet channel at the beginning of the level grade through the outlet.

Such storage possibilities seemed more favorable from the point of view of cost than storage in the Mud-Camas Reservoir for an additional supply from Camas Creek. Accordingly, detail topography of the dry playa lake in the bottom of Coleman Valley was taken on a scale of a half mile to the inch. This topography,

with the high line run around the valley by Mr. Dubuis in 1911, gives fairly accurate data for determining areas and capacities in this valley. The storage capacity of Coleman Valley could be increased to 120,000 acre-feet by building a 10-foot dike across the entrance and providing a pumping plant to pump water from the dredged channel over this dike; 90,000 acre-feet of this water could be withdrawn without pumping.

Following is a tabulation of the area flooded and the capacity in acre-feet of Coleman Valley to the elevation of the contours indicated in the first column.

Coleman Valley Reservoir site.

Contour elevation.	Area.	Capacity.
Feet.	*Acres.*	*Acre-feet.*
4,450	930	625
4,455	1,840	7,600
4,460	2,720	19,000
4,465	3,650	34,800
4,470	4,700	55,600
4,475	5,500	81,200
4,480	6,200	110,400
4,495	8,000	217,000

BIG VALLEY RESERVOIR SITE.

Big Valley Reservoir site is located in T. 40 S., R. 22 E., about 14 miles up Deep Creek from Adel. The reservoir site is a large open valley, the greater part of which is given over to the grazing of cattle. Some wild hay is cut. About one-third of the area—the northern part of the valley—has not been irrigated and is covered with a growth of dwarf sage. The drainage area tributary to this site is 71 square miles, nearly all of which is heavily timbered, reaching an elevation of about 7,000 feet in the mountain region overlooking Goose Lake Valley on the west. Several streams enter the valley from the south and west to form Deep Creek, which leaves the valley through a narrow outlet affording an excellent dam site. (See Plate No. 1.)

The discharge of Deep Creek from this reservoir site ranges from 32,300 acre-feet in 1915 up to 56,700 acre-feet in 1913–14. (See "Water supply.") The probable mean discharge is estimated to be 50,000 acre-feet, which is about 40 per cent of the mean yearly discharge of Deep Creek at Adel. The mean run-off during the period in which records were kept at Big Valley is about 14 inches, and the precipitation in the drainage area is probably less than 24 inches.

Following is a tabulation of the capacity of the reservoir site in acre-feet and the area of land that would be flooded by a dam raising the water to elevations given in the first column.

Big Valley Reservoir site.

Depth.	Area.	Capacity.
Feet.	*Acres.*	*Acre-feet.*
10	80	400
15	1,220	3,400
20	2,440	13,000
25	2,900	26,500
30	3,200	41,700
35	3,360	58,100
40	3,520	75,300
45	3,750	93,500
50	3,840	112,400

MUD-CAMAS RESERVOIR SITE.

This reservoir site is located approximately 15 miles west of Adel on Camas Creek, at an elevation of about 5,450 feet at the dam site. The dam site is at a contraction of the canyon forming the reservoir site, which has a width varying from 500 feet to a quarter of a mile. The walls of the canyon at this dam site are characteristic rim rock with talus slopes of broken lava. An 87-foot dam at this site would back the water up Camas Creek about 6 miles and up Mud Creek about 2 miles. Mud Creek joins Camas Creek about 3 miles west of the dam site. A dam 87 feet high at this site would be 150 feet long at the surface of the creek and 650 feet long at the crest line, to raise the water 80 feet at the dam. With a dam at this height, raising the water 80 feet, the storage capacity is about 41,000 acre-feet, and 1,100 acres would be flooded.

Portions of this narrow valley furnish good grazing for sheep and cattle. The main road from Lakeview to Adel runs lengthwise through this reservoir site, on the north side of Camas Creek. The territory drained by Mud Creek and Camas Creek is about 87 square miles. It is of much the same character as that drained by Deep Creek, though lower. The records of discharge indicate a smaller annual run-off, probably little, if any, in excess of 30,000 acre-feet.

The probable cost of storage development for 41,000 acre-feet is as follows:

Embankment, 230,000 cubic yards, at $0.60	$138,000
Temporary diversion, spillway, and outlet works	40,000
Lands, 1,100 acres, at $20	22,000
Engineering, administration, and contingencies, 25 per cent	50,000
Total	250,000

The cost of this storage is about $6 per acre-foot of storage capacity and $8.30 per acre-foot on the estimated amount of 30,000 acre-feet available in mean years for irrigation.

Following is a tabulation of the capacity of the reservoir site in acre-feet, and the area of land that would be flooded by a dam raising the water to elevations given in the first column:

Mud-Camas Reservoir site.

Depth.	Area.	Capacity.
Feet.	*Acres.*	*Acre-feet.*
10	35	200
20	148	1,100
30	368	3,500
40	534	8,000
50	696	14,200
60	844	21,900
70	965	31,000
80	1,080	41,200

CRANE LAKE RESERVOIR SITE.

This reservoir site is located on Crane Creek, a tributary of Camas Creek, about a mile south of the lower portion of the Mud-Camas Reservoir site, from which it is separated by a ridge about half a mile wide. The site appears to be an excellent one for a capacity of about 25,000 acre-feet, requiring a 45-foot dam at the outlet. The tributary drainage area is about 15 square miles, and the run-off in 1913–14, the only year when measurements were taken, was about 3,500 acre-feet. The bottom level lands, approximately 1,000 acres in extent, provide wild hay by early spring flooding, and it therefore seems not improbable that this reservoir site may have as much as 5,000 or 6,000 acre-feet run-off in mean years. The lands alone would probably cost $15,000 to $20,000, and the reservoir site is therefore probably impracticable for storage of Crane Creek waters alone.

The possibility of diverting Camas Creek to the Crane Lake Reservoir site should be investigated, although it is not believed now to be feasible. The Crane Lake dam would have to be 45 feet high and about 600 feet long at crest line for 25,000 acre-feet capacity, which, with the reservoir lands, would probably cost at least $120,000, or nearly $5 per acre-foot of storage capacity. It can therefore readily be seen that the cost of diversion of Camas Creek into Crane Lake Reservoir site would have to be very small to make such a plan more economical than the Mud-Camas storage, which would probably cost about $6 per acre-foot of storage capacity, as already shown.

Following is a tabulation of the capacity in acre-feet of the reservoir site and the area of land that would be flooded by a dam raising the water to elevations given in the first column:

Crane Lake Reservoir site.

Depth.	Area.	Capacity.
Feet.	*Acres.*	*Acre-feet.*
10	10	50
20	864	4,420
30	1,045	13,950
40	1,194	25,150
50	1,300	37,600
60	1,445	51,400

SNYDER CREEK RESERVOIR SITE.

Snyder Creek Valley, on Snyder Creek, about 10 miles northwest of Plush, is a large, open valley covered generally by sagebrush, although a ranch in the north end of the valley owned by W. Z. Moss is partly improved, and some hay is raised by diverting waters from one of the small streams entering the valley. The immediate tributary area is not timbered, but the area beginning a few miles west of the valley and extending to the rim at the south end of Lake Abert, reaching an elevation of about 6,000 feet, contains more or less forest.

A topographic survey was made of this reservoir site by the Warner Lake Irrigation Co. in 1910 on a scale of 1 inch to 500 feet. During that particular year the run-off available for storage at this site was unusually heavy, due to the early melting of the deep snow on the adjacent table-lands. This run-off is estimated to have been from 10,000 to 15,000 acre-feet, and no doubt accounts for the survey of the reservoir site being undertaken at that time. The run-off in 1911 (see "Water supply") is estimated to have been from 6,000 to 7,000 acre-feet, and in 1915 about 750 acre-feet. The mean yearly run-off is probably not much more than 2,000 acre-feet.

Following is a tabulation of the capacity of the reservoir site in acre-feet and the area of land that would be flooded by a dam raising the water to elevations given in the first column.

Snyder Creek Reservoir site.

Depth.	Area.	Capacity.
Feet.	*Acres.*	*Acre-feet.*
0	20	20
25	168	2,370
40	476	7,200
50	682	13,000
60	1,006	21,400
70	1,331	33,100
80	1,669	48,100
90	2,021	66,500
100	2,373	88,500
110	2,718	114,000
115	2,890	128,000

HONEY CREEK RESERVOIR SITE.

This reservoir site is located about 2 miles south of the Synder Creek site and is practically a canyon about a quarter of a mile wide and 2 miles long. (See Plate No. 1.) The valley lands are wild hay lands. The drainage area tributary to this reservoir site is much more favorable for an ample water supply than that of Snyder Creek, as the streams drain the north and east slopes of Drakes Peak, reaching an elevation of 7,500 feet. The only records of discharge available are for the seasonal year of 1911–12, shown in discharge records as "Honey Creek near Chalstrand's." The discharge is given as 17,500 acre-feet. During the same period Honey Creek at Plush discharged 54,300 acre-feet, compared with a mean yearly average of about 23,000 acre-feet. In the same year Twelvemile Creek discharged 9,200 acre-feet into Honey Creek, leaving 27,600 acre-feet to be the flow to Honey Creek from Snyder Creek and other lower tributary area, which in ordinary years would probably not supply more than 2,000 acre-feet. From this meager information the ordinary run-off available at Honey Creek reservoir site is assumed to be about 14,000 acre-feet. Storage for this capacity requires approximately an 80-foot dam with crest length of 1,000 feet. The cost of this storage would probably exceed $200,000, say $15 an acre-foot of storage capacity, and it is therefore not considered for any project proposed.

A topographic survey was made of this reservoir site by the Warner Lake Irrigation Co. on a scale of 1 inch to 500 feet, and the survey connected by a transit line with that of the Snyder Creek reservoir site. This survey shows the Honey Creek reservoir site to be about 20 feet lower at the dam site than that of the Snyder Creek site. It is therefore not feasible to carry Honey Creek waters into the Snyder Creek reservoir site for storage purposes except by canal diverting so far above Honey Creek reservoir site as to be impracticable on account of the cost.

Following is a tabulation of the capacity in acre-feet of the reservoir site and the area of land that would be flooded by a dam raising the water to elevations given in the first column:

Honey Creek Reservoir site.

Depth.	Area.	Capacity.
Feet.	*Acres.*	*Acre-feet.*
10	40	200
20	88	830
30	149	1,980
40	222	2,830
50	296	5,420
60	382	8,800
70	478	13,100
80	562	18,300

COWHEAD LAKE RESERVOIR SITE.

Cowhead Lake is located about 20 miles south of Adel and 5 miles south of the Oregon-California State line, near the divide between Warner Valley and Surprise Valley in California. It is probably the only available storage site in the Twentymile Creek watershed. The value of this storage site for the streams from the 40 square miles of tributary area is very doubtful, as an examination of the discharge records of Twentymile Creek near Warner Lake post office (see "Water supply") indicates that in 1912, 1913, and 1915 there was probably very little if any discharge from Cowhead Lake into Twentymile Creek. The large area of 2,700 acres at the outlet elevation of the lake would result in heavy losses by evaporation.

No survey has been made of this reservoir site for purposes of this investigation, but the following notes on the plans of the Modoc County Irrigation Co. give all of the available data for evaporating area and cost of dam at the outlet of the lake:

Modoc County Irrigation Co. project.—This project contemplates the irrigation of a long and relatively narrow strip of land lying along the east side of Surprise Valley. The tract lies mainly in California, but at its southern end extends into Nevada.

A report made to the company in 1911 by Charles Kirby Fox, then chief engineer, proposed the irrigation of 40,000 acres. This area will undoubtedly have to be materially reduced, as the records of stream flow taken since 1911 indicate that the available water supply will hardly suffice for half this area.

The main features of the project comprise a reservoir of large capacity at Cowhead Lake, feed canals to divert water from the tributaries of Twentymile Creek, a tunnel extending through the divide at the south end of Cowhead Lake to deliver the water into Surprise Valley, a main canal and distributing system. Cowhead Lake at its present level of overflow has an area of about 2,700 acres. The area will be increased to 4,800 acres, and a reservoir with a capacity of 125,000 acre-feet formed. The dam as proposed will have a height of 43 feet, a length varying from 132 feet at the base to 350 feet on top, and a cost probably of $35,000. The length of proposed tunnel is 4,650 feet, its capacity 370 second-feet, and its probable cost $58,000. The main canal as surveyed has a total length of 44.7 miles, of which 22 miles has a capacity of 300 second-feet or over. The diversion canal from Twelvemile Creek diverts near the upper end of the small valley occupied by the Conlan ranch, and is about 2 miles long. An extension of this canal a little over a mile long will be required to bring in the waters of Fifteenmile Creek.

It is also possible to divert the headwaters of Dismal Creek over a saddle at the head of Twelvemile Creek. This can be accomplished

by a short canal at a relatively low expense. The diversion will have to be made in Oregon, but the source of practically all of the water supply is south of the State line.

A survey has also been made for a canal diverting from Deep Creek above Big Valley and extending to a divide at the head of Fifteenmile Creek. The cost of such a diversion would be considerable, and the maintenance cost would undoubtedly be high, as the elevation of the canal would be close to the 6,000-foot contour. It is also doubtful whether rights for this diversion could be secured from the State of Oregon, as the source of the water is mostly in Oregon.

The canal for diverting the waters of Rock and Keno Creeks would be about 3 miles long. It would have to be of large capacity and would run full for only short periods, as the run-off of these streams is very flashy.

There are two small lakes along the line of the proposed canal in which it might be possible to store some waters from the peak flood, thus enabling a reduction to be made in the capacity of the canals below this point. The probable cost of the diversion canals from Twelvemile and Rock Creeks is $48,000. This does not include the Dismal Creek or the Deep Creek diversion.

Storage possibilities in Cowhead Lake.—The storage possibilities in Cowhead Lake are rather uncertain because of the small amount of data available as to the direct discharge into that lake from the present drainage area and of the streams which might be diverted into it. A study of the topography and position of the Cowhead drainage basin with respect to the whole drainage basin of Twentymile Creek makes it seem probable that the run-off into Cowhead Lake would not much exceed that of the mean for the 118 square miles, including the area drained by Fifteenmile Creek at its junction with Horse Creek. An estimate has been made of the probable run-off of Twentymile Creek drainage area of 200 square miles, including 40 square miles of Cowhead Lake drainage area.

A study of the character of the drainage area of Twentymile Creek and of the discharges of the tributaries of that stream in 1913 (see "Discharge records") indicates that nearly the entire flow of Twentymile Creek in years of low to mean discharge probably came from the 118 square miles of drainage area tributary to Fifteenmile Creek at and above its junction with Horse Creek. This includes the area drained by upper Fifteenmile and Twelvemile Creeks, Cowhead Lake outlet, Keno, Rock, and Horse Creeks. In fact, the records ot discharge above referred to indicate that the discharge of Fifteenmile Creek below Horse Creek for the period when measured was greater than that of Twentymile Creek near Warner Lake, which would indicate a loss of water in Twentymile Creek. It is more probable, however, that the measurements taken of Twentymile Creek, but one a

day, did not show large enough discharges because of the diurnal fluctuations due to the rapid melting of the snow during short periods of the day.

It is evident from these records that the remaining area of 78 square miles, tributary to Twentymile Creek, probably furnishes very little yield in years of low and ordinary run-off. This area is 40 per cent of the total area of 196 square miles drained by Twentymile Creek, and in years of high run-off probably would not furnish over 20 per cent of the entire run-off. It is so estimated in arriving at the probable discharge per square mile for the higher drainage area in the years 1909–10, 1910–11, and 1913–14.

Following is a tabulation leading up to the probable discharge into Cowhead Lake during the six years of record, 1909–10 to 1914–15, inclusive. The columns indicated by numbers represent:

(1) Recorded discharge of Twentymile Creek near Warner Lake. (See "Discharge records.")

(2) Probable yearly evaporation from the 2,700 acres of surface of Cowhead Lake, assuming that the evaporation over the surface of the lake exceeds by 2½ feet a precipitation estimated to be about 1½ feet.

(3) Total estimated run-off for Twentymile Creek and Cowhead Lake. Sum of columns 1 and 2.

(4) Probable run-off per square mile from the 118 square miles tributary to Fifteenmile Creek (above Twentymile Creek) and Cowhead Lake. For the first, second, and fifth years, eight-tenths of column 3 is taken as the discharge from the 118 square miles.

(5) Probable inflow to Cowhead Lake from 36 square miles of tributary area.

Probable inflow to Cowhead Lake.

Year.	1 Recorded discharge, Twentymile Creek.	2 Estimated evaporation, Cowhead Lake.	3 Estimated run-off of creek and lake.	4 Probable run-off per square mile Fifteenmile (above Twentymile) and Cowhead.	5 Probable inflow to lake from tributary area.
	Acre-feet.	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*
1909-10	67,300	6,800	74,100	500	18,000
1910-11	47,900	6,800	54,700	370	13,400
1911-12	16,000	6,800	22,800	195	7,000
1912-13	18,500	6,800	25,300	215	7,700
1913-14	41,700	6,800	48,500	330	11,800
1914-15	18,700	6,800	25,500	215	7,700
Total, 6 years	210,100	40,800	250,900	1,825	65,600
Mean	35,000	6,800	41,800	304	10,930

The economic diversion from Rock and Keno Creeks would probably amount to something like the total run-off shown in records of

discharge for those streams in 1913 between March 7 and June 17, or about 5,000 acre-feet. The run-off of Twentymile Creek this year was about 40 per cent below the normal. The application of this percentage to Rock and Keno Creeks makes a probable discharge of 8,300 acre-feet for the normal year. Possibly as much as 60 per cent of this discharge, or 5,000 acre-feet, could be diverted. The diversion in years of higher discharge would probably be something in excess of this amount.

The run-off from Twelvemile Creek and upper Fifteenmile Creek appears from the records to come later in the season, and on this account such varying discharges may not be expected. It is therefore thought that it may be practicable to divert possibly as much as 80 per cent of the mean discharge, taken at 13,300 acre-feet, or 10,600 acre-feet, to Cowhead Lake. The mean yearly inflow from the three sources considered then amounts to 26,500 acre-feet. With the difference between loss due to evaporation and gain due to precipitation, resulting in a net loss of 2½ feet in depth on the lake surface, varying from 2,700 acres to 3,000 acres, the total loss will amount to about 6,500 acre-feet, leaving available for irrigation 20,000 acre-feet.

The outlet of Cowhead Lake has a very slight grade for about a mile below the lake to the dam site proposed by the Modoc County Irrigation Co., described above, so that development to draw the lake surface down below the present outlet elevation would probably prove expensive. It thus appears that the use of Cowhead Lake for storage of a supply for Warner Valley lands would be wasteful of water by evaporation from the relatively large area of the lake, and that it would prove impracticable to carry over storage from one year to another. The plan of the Modoc County Irrigation Co., which provided for tapping the bottom of the lake with a tunnel, might be expected to cut down the evaporation losses to possibly as little as 1,500 acre-feet, leaving available under this plan about 25,000 acre-feet.

Using the probable cost of $83,000 found by the Modoc County Irrigation Co. for the Cowhead Lake storage dam and the diversion canals from Twelvemile Creek and Rock and Keno Creeks, the cost per acre-foot for water which might be used in Warner Valley in normal years is $4.15 per acre-foot.

SOIL AND AGRICULTURAL SURVEY.

A preliminary soil and agricultural survey of Warner Valley was made by W. L. Powers, assistant professor of agronomy, Oregon Agricultural College, assisted by O. B. Hardy and L. R. Breithaupt, and the following statement has been prepared by them.

Warner Valley is a long, narrow depression extending north and south on the eastern edge of southern Lake County. The main valley averages perhaps a township wide and over 50 miles in length. The valley is the result of a double fault and has steep walls, particularly on the east. The valley floor is mainly of sedimentary material. Some marsh land in the upper valley has given rise to a cumulose soil, while along the edges of the valley near the rim rock is some colluvial material, and an arm of the valley extending into what is known as Rabbit Valley appears to be partly of residual character. There are three small areas of alluvial material deposited by the main streams entering the valley. The average elevation of the valley floor is about 4,600 feet above sea level.

CLIMATIC CONDITIONS.

The climate is arid in character, and the annual rainfall is about 10 to 15 inches. The maximum precipitation occurs in winter, with a secondary maximum in late spring. In the floor of the valley frosts are likely to occur any month of the year, although from 6 to 10 weeks, usually in midsummer, are fairly free from frost. The slopes near the edge of the valley, particularly in the vicinity of Adel, have good air drainage and are sheltered by high rim rock so that some good home orchards are found to produce fairly well.

AGRICULTURAL DEVELOPMENT.

The settlement of this region began about a generation ago. There is a large amount of surrounding range land, and the stock interests largely control the hay ranches and marsh land which are used for winter feeding or wintering young stock. The valley also serves as the center for the stock industry of the region on account of the scarcity of water on the surrounding range. The valley is sparsely settled, with villages at Plush, near the mouth of Honey Creek, and at Adel, near the mouth of Deep Creek. Cultivated crops are limited to a small amount of rye and alfalfa, and a limited number of small gardens and home orchards. Considerable areas of wild hay are harvested for winter feeding.

SOILS.

The original source for most of the soil material in this area comes from basalt which is the country rock in most of the region. Soils of the area, being mainly of sedimentary origin, are somewhat darker in color and finer in texture than are most of the arid soils. Beginning at the rim of the valley there is some soil in Rabbit Valley and near the rim of Warner Valley which may be underlain with basalt and is residual soil. Part of the area in Warner Valley next to the rim may be colluvial material, but in no case has this strip of soil

next to the rim rock been moved far from the parent rock, so colluvial and residual soil have all been placed in one general type. Below this is found fine sand and very fine sandy loam which is mainly sedimentary. Three principal streams entering the valley from the west have deposited alluvial fans inside of the valley floor. Still lower there is a more or less continuous fringe of mud flats or clay, which is most extensive in the north or lower part of the valley. In the upper valley south of Hart Lake the marshy condition has given rise to peat soils. At the edge of the marsh, peat forms only a shallow mat on the surface. Farther out the peat is of medium depth, and next to the open water there is deep peat, the chief areas of this being at the south end of Hart Lake and the tule land south of Adel.

Soils of the region may be classed in three groups, namely, the marsh soils, the lake beds and terraces, and the black sage lands which are slightly elevated above the present valley floor. The first two classes of soil have good depth. All except the marsh soils have been reworked some by wind action. On the east slope, especially in the vicinity of Adel, where the sand has been more exposed to the sunshine, a larger amount of decomposition has taken place. The extent and location of different soil types as determined are shown on soil map, Plate No. 2. The following table gives the names and approximate extent of different soil types in Warner Valley.

Soil types of Warner Valley.

Name of type.	Approximate area, in acres.	Per cent of total area.
Black sage land, medium to coarse sand	64,400	31.8
Lake terrace soils:		
Fine sandy loam	9,150	4.5
Very fine sandy loam	57,850	28.6
Silt loam	7,000	3.4
Clay	42,000	20.7
Marsh soils:		
Peaty silt loam	4,750	2.3
Muck	11,600	5.7
Deep peat	5,550	2.7
Total	202,300	100.0

BLACK SAGE UPLAND.

Medium to coarse sand.—Medium to coarse sand, or black-sage land, is found near the rims of the valley, especially where the slopes below the rims are more extended. The main bodies of this type of soil occur toward the north part of Warner Valley and in Rabbit Valley where the rim rock is less prominent. Toward the lower part of the slope and in the sunny exposures, as in the vicinity of Adel where the land has been cropped for a great many years, there is less coarse material present, while at the higher parts

of the slopes the coarse grades of sand are more abundant. This area has only a medium depth. There are few places where the third foot could be dug without pick work. On the slopes in the vicinity of Adel now in alfalfa, and on the slopes on the south side of the mouth of Rabbit Creek, a third-foot sample was secured with a spade. Much of Rabbit Valley and the north end of Warner Valley are covered with this type of soil. The surface is rather gritty, but becomes dense hardpan within 10 to 15 inches of the surface. The second foot is made up of siliceous material which cements together numerous fragments of basalt, and at least in parts of Rabbit Valley solid basalt appears to be within 2 or 3 feet of the surface.

The lower slopes of this area would irrigate successfully, but much of the area is at too high an elevation above the source of water, or too steep, coarse, and shallow to warrant serious consideration in connection with the present irrigation scheme. The sage brush on this type of soil is of medium size and in places on the shallower parts of the area the brush is dwarfed. On account of the inaccessibility of this type of soil and its limited water capacity it does not appear attractive for irrigation purposes at the present time. Mechanical analysis of the coarse sand and medium sand phases of this type are given in the following table. These and other mechanical analyses given herein are made by C. V. Ruzek, assistant professor of soils, Oregon Agricultural College from samples collected by the writer.

Mechanical analyses of medium to coarse sand.

Soil.	Section.	Township S.	Range E.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
				Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
No. 9, surface.....	SW. ¼ 15	39	24	2.96	7.56	8.10	34.28	32.52	8.32	6.20
No. 6, surface.....	C 15	27	32	14.18	10.42	5.72	17.42	38.42	7.27	5.02

Fine sandy loam.—Brown fine sandy loam occurs along Rabbit Creek and extends out to the Flagstaff Lakes, into which this creek discharges. There is also a small area near the mouth of Twentymile Creek. This soil has very good texture for irrigation purposes, and has fairly good depth. Vegetation is mainly black sage, which is generally fairly thick, of good height, and is making considerable growth. There are places where a little greasewood is mixed with this black sage near the mouth of Rabbit Creek, but generally this type is located close to the stream channels, where it has had fairly good natural drainage. It is believed that this type of soil, although small in extent, could be utilized for irrigation purposes as far as accessible.

LAKE TERRACE SOILS.

Very fine sandy loam.—The very fine sandy loam occupies a large part of the valley floor, extending from the base of the black-sage slope out to near the areas at present affected by water. This soil varies from yellowish brown to dark brown in color. The land is generally flat and alkaline, and is covered with a growth of greasewood. A little loose sand has drifted over the surface or settled around the clumps of vegetation in places. The soil is of good depth but becomes hard in the second foot, due to silicate or alkali hardpan, while the subsoil is quite heavy. This land would be very difficult to drain, and at the high altitude of this valley underdrainage would be out of the question. Where deep channels are close at hand a limited amount of this area might be flushed off. On account of the landlocked character of the valley, however, there is not much chance of washing the salt away from this land, as would be necessary to complete its reclamation under irrigation. In addition the texture of this subsoil, and even the surface in places, is so heavy that it renders the soil rather cold and liable to puddle under irrigation, so it does not appear feasible to attempt to reclaim this type of soil, all conditions considered. The mechanical analysis of a representative sample of this type follows:

Mechanical analysis of very fine sandy loam.

Soil.	Section.	Township S.	Range E.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
				Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
No. 8, surface.....	E. ½, 8	33	26	Trace.	0.54	0.86	10.30	58.30	20.52	10.08

Silt loam.—Dark silt loam occurs in the deltas of Honey Creek, Twentymile Creek, and Deep Creek. These lands are irrigated and in natural meadow at the present time. On the better part of this meadow the wild hay is cut for winter feed and is said to yield a ton to the acre. The soil has some slope and is favorably located in relation to the streams at present used for irrigation, so that altogether this is one of the best soils in the valley. With improved drainage much of this land could be used for clover and timothy, and in the more elevated portions of the area it is very likely that alfalfa would succeed with better drainage. These crops should yield 2 to 3 tons per acre with soil moisture controlled. The mechanical analysis follows:

Mechanical analysis of silt loam.

Soil.	Section.	Township S.	Range E.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
				Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
No. 3, surface.....	SW. ¼, 27	39	24	0.38	3.64	2.88	8.42	20.22	48.08	14.86

Clay.—Brown to black clay or mud plats occupy areas that are periodically inundated in North Warner Valley and extend over a more or less continuous area slightly above the water level along the east side of South Warner Valley east of Crump Lake. The surface of this type is very hummocky, and considerable alkali is visible in places. A sample of this soil which was analyzed contained 47.5 per cent clay. This sample was taken from Bluejoint Lake, so named from the crops of blue joint grass which spring up there and are used for pasture or are cut for hay in the best seasons. The vegetation on this type of soil north of Hart Lake is salt grass, wire grass, and other native grasses, with sedges in the lower spots in the area. This vegetation is of moderate value for pasturage. On account of the heavy character of the soil, grasses are best adapted to this land. With a better control of the water, red top and other cultivated grasses would improve the productiveness of this land to some extent. On account of the very heavy nature of this soil, which makes it cold and difficult to manage, it is not very desirable land for irrigation at such an altitude. Systematic irrigation would be of some value to those portions of this type of soil that have the highest carrying capacity at present, because more sand is contained in the clay between Hart and Anderson Lakes. Mechanical analysis of a representative sample of this soil follows:

Mechanical analysis of clay.

Soil.	Section.	Township S.	Range E.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
				Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
No. 7, surface.....	12	33	26	Trace.	0.52	1.46	8.76	22.82	20.12	47.50

MARSH SOILS.

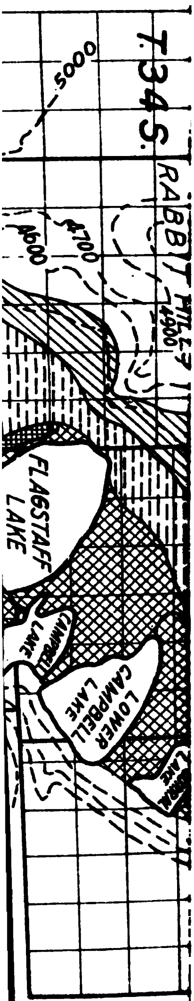
Peaty silt loam.—Peaty silt loam occurs on the edges of the marsh below the deposit of silt loam brought down by Deep Creek and Twentymile Creek. The surface mat of peat varies in thickness from 1 to 2 inches to a foot or more, while the underlying soil is not different from the silt loam now in natural meadows. There is

a good supply of organic matter in the subsoil. Native grasses grow on this type of land. There is also a large per cent of sedges present. The so-called "sugar grass" (*carex aquatilis*) and the three-cornered sedge abound in the lower parts of this area. Much of the area is cut for feed, though in lower places tules are present. This coarse feed is usually cut and piled up in small cocks, from which the stock feed in the winter. The control of the water by drainage and a little systematic irrigation would permit growing cultivated grasses and clovers and would more than double the food-producing value of this type of soil.

Muck.—The main area of muck occurs north of Adel along the east side of Crump Lake. There is a medium depth of peat, averaging perhaps 2 feet, the peat increasing in depth toward the open water. The subsoil is a mixture of organic and inorganic material, the former being fairly well decayed. The inorganic substances range from gritty to rather sticky materials. The subsoil seems to become heavier toward the north end of the area where the subsoil would be clay loam. There may be a little deep peat along the edge of Crump Lake. This locality was very inaccessible, and the exact depth of the surface mat was not determined. A rank growth of tules covers most of the area. It is believed that this land could be drained and brought into very profitable production. Irrigation would need to be applied if full control of moisture conditions on this type of soil is to be provided.

Deep peat.—The area covered by the thick tule beds are south of Adel, and in other places near the open water is a deep raw-peat soil. Such a soil is composed largely of vegetable matter and is very light in weight, extremely porous, and has a high water-retaining capacity. This area seems to have good depth. A 6-foot soil auger failed to reach the bottom of the peat layer. Drainage of this land appears readily feasible, for a deep raw-peat soil is rather porous and responds readily to the action of drains. Drainage is the first step in the improvement of such soils. The heavy growth of tules can be burned off when the tops are dry and when the soil is wet nearly to the surface so that the vegetation is removed without destroying much of the valuable soil material. Peat soils frequently require liming or potash to bring them into their highest state of productiveness. They are usually rich in nitrogen and well supplied with phosphorus. This area is regarded as one of the most promising bodies of soil in the valley. At the altitude and under the conditions at which it is situated this land would probably be utilized for the production of grasses and other hardy forage plants when reclaimed. Such lands generally require some irrigation after thorough drainage has been provided.

WARNER



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SOIL FERTILITY AND ALKALI.

Representative samples of soils collected in Warner Valley were analyzed by Mr. R. H. Robinson, of the Oregon Experiment Station, with results as follows:

Soil.	Total potash (K_2O.)	Total phosphorus.	Total nitrogen.	Alkali.	Acidity.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	
No. 6. Surface, medium coarse sand; black sage land; sec. 15, T. 27 S., R. 32 E.	1.97	0.38	0.06	....	
No. 2. Surface, peat; tule land; sec. 5, T. 40 S., R. 24 E.	.67	.28	1.25	....	
No. 8. Third foot, fine sandy loam; greasewood land; sec. 8, T. 33 S., R. 26 E.	....	....	....	0.21	
No. 8. Surface, fine sandy loam; greasewood land; sec. 8, T. 33 S., R. 26 E.	....	....	....	.076	
No. 7. Surface, clay; salt grass land; sec. 12, T. 33 S., R. 26 E.	....	....	....	1.17	
No. 2. Third foot peat; tule land; sec. 5, T. 40 S., R. 24 E.	....	....	....	....	5,500 pounds $CaCO_3$ per acre-foot.

These results were discussed by Prof. H. V. Tartar, station chemist, as follows:

The quantity of total phosphorus in the samples Nos. 6 and 2 (surface) is very good, comparing very favorably with other productive Oregon soils. The nitrogen in sample 6 is low, while in sample 2 (surface) it is very high. As a rule, Oregon soils contain around 0.20 per cent of total nitrogen. Sample 2 (surface) contains as much nitrogen as is found in our so-called "beaverdam" soils. The potash in sample 6 is very good—about average—while in 2 (surface) it is quite low. Other peat soils in this State containing this low a potash content have responded readily to fertilizers containing this plant food.

The content of alkali salts in sample 7 (surface) is very high—too high to permit the growing of agricultural crops on that soil. In the case of soil No. 8, the alkali is much higher in the subsoil than in the surface soil. The amount of soluble salts present is sufficient to make their presence a matter of serious consideration in the irrigation of this soil.

The acidity of sample 2 (surface) is considerable, requiring 2¾ tons of ground limestone per acre to neutralize the acidity to a depth of 12 inches. It may be said, however, that profitable crops are grown without the use of lime on many peat soils which have an acidity as great as this sample.

DRAINAGE.

Drainage of the marsh soils in South Warner Valley appears to be the most attractive field for reclamation in the area surveyed. In controlling the water of the district, some irrigation could be provided for these lands after drainage, and some dikes and control gates would improve the productiveness of the marshland and other lands in the valley floor in the lower part of Warner Valley or adjacent to and north of the Warner Lakes. In draining peat lands it should be kept in mind that these soils shrink upon drainage, as does a

sponge upon losing its excess water. A further cause of their shrinkage is the rapid decomposition after the excess of water is removed and the air is allowed to enter. The mat of peat can be expected to shrink from one-quarter to one-third its volume, and this may mean the lowering of the surface elevation of this deep peat area as much as 2 feet within a decade after drainage. The raw peat soils will stand with rather steep banks and frequently the ditch banks are made with one-half foot of run to one rise. Main ditches for drainage would include a channel through the lower part of the marsh and ditches along the edges of the marsh to pick up water from streams and higher lands. In raw peat that is of good depth but few lateral drains are required. In medium peat or muck the laterals may need to be increased a few years after drainage has been provided, as the soil becomes somewhat more compact and the supply of humus decreases. The deep peat and the muck soils produce nothing at present but tules and other water-loving vegetation. With drainage it is believed they would become the most productive soils in the valley. Drainage of these soils appears to be the most attractive field for reclamation in Warner Valley.

IRRIGATION.

Irrigation of the marshland will probably be required after thorough drainage, and this can be at least partly accomplished by subirrigation. The main drainage channels, if provided with control gates which may be closed when the land is nearly drained out, will help to control the water table and hold it at a favorable distance below the surface. The grass lands may be irrigated by simply using some large field laterals which will spread the water over the slopes and raise the water table to the grass roots. Grasses will generally keep green and make good growth where the water table is 1½ or 2 feet below the surface. Timothy and clover should do well with the water table 3 feet from the surface, while grain and alfalfa will be better with the water table some 4 feet below the surface. On the silt loam soil the field-lateral system of distributing the water could be improved, and with the land in alfalfa probably the strip-border method would make a further improvement in time. Garden stuff or row crops would generally be irrigated by the furrow method.

It is estimated that the duty of water for the organic soils, subbing disregarded, would be similar to the requirement of the silt loam. Meadow crops will constitute the main crops grown on these lands, and, while the minimum allowance for such crops would be perhaps 1½ acre-feet per acre for the season, the control of water will no doubt provide a more liberal supply. The silt loam soil has good usable water capacity, and would retain perhaps an inch and a half

of usable water per acre-foot. Some of the clay soil now in salt grass and wire grass could be improved in its productiveness with the water better controlled and applied as the plants need it, and with the control of moisture better grasses could be grown. On account of the slow rate at which this soil takes up water, flooding and allowing considerable time for the soil to absorb water will be necessary. Fine sandy loam will take up moisture readily, and is about the right texture for a soil to be used for irrigation at this altitude. Fine sandy loam will require a little more water than the silt loam. The medium to coarse sand, being limited in depth and rather coarse in texture, will require rather frequent irrigations, and it is probable that 3 or 4 acre-feet per season per acre is used on this land where irrigated at present. The corrugation or furrow method is used in distributing water over this land at present in some alfalfa meadows. On account of this type being too steep for border method of irrigation field laterals located along the contours, and ultimately corrugations through the land under these laterals, will probably be the best method of distributing water on this type of soil where irrigated.

VALUE AND FEASIBILITY OF RECLAMATION.

Altogether the marsh soils appear to be the most inviting field for reclamation in Warner Valley. In working out a project the fine sandy loam could be included as far as accessible and some of the lower slopes of the medium to coarse sand where it has fair depth could be included. Systematic control of the water on the clay land might improve its productiveness, say, one-half ton per acre. This hay fed to range cattle and sheep in Warner Valley should pay interest on a land value of about $25 to $35 per acre. There is a shortage of hay in proportion to range in the region.

In the improvement of the marshlands drainage is the primary requirement and irrigation is to be regarded as supplemental and secondary. The areas most desirable to reclaim are as follows: Deep peat, 5,500 acres; muck, 11,600 acres; peaty silt loam, 4,750 acres; fine sandy loam, 9,150 acres; and silt loam, 7,000 acres.

The latter type would not properly be reclaimed, but its productive capabilities should be doubled by systematic control of soil moisture conditions. Part of the fine sandy loam is rather inaccessible. On the other hand, some of the lower slopes of the medium to coarse sand might be reclaimed and some portions of the clay areas could be improved by providing a favorable moisture condition. The clay north of Hart Lake and in the vicinity of Anderson Lake contains some sand. From the vegetation there, it appears to be of a little better character than the average for that soil. The clay land in Bluejoint Lake also is said to have merit.

The marshlands that now carry only a swamp growth should become very productive with drainage and supplemental irrigation, and should produce from 2 to 3 tons of clover and timothy or other forage crops. The silt loam, with good drainage and proper irrigation, should produce 2 or 3 tons of alfalfa, as is now secured on the better phases of the medium sand, where readily accessible to irrigation. Perhaps a ton of redtop and other grasses might be produced on the better part of the clay soil when moisture conditions are controlled. Altogether it appears very feasible to reclaim some 30,000 acres of marshland. In addition there are at least 20,000 acres of adjoining land that could be greatly improved in its productiveness by a system of water control, and it appears feasible to make this improvement if water control can be provided at moderate cost.

LAND OWNERSHIP.

A large part of South Warner Valley is in private ownership. The Warner Valley Stock Co. owns 20,000 acres known as the M. C. ranch.

In North Warner Valley the Lake County Land & Livestock Co. owns about 7,000 acres of the lands west and north of Hart Lake. These lands are known as the 7–T ranch. The Oregon Valley Land Co. owns about 1,900 acres of the sagebrush lands immediately north of Plush. Practically all of the irrigable lands north of Flagstaff Lake is in a Carey Act selection made by the Warner Lake Irrigation Co., and is unpatented. Of the 12,000 acres in the Rabbit Creek Basin, which might be irrigated by a 120-foot pump lift, about 2,600 acres is privately owned land, in parcels of 160 to 320 acres, the remainder being public lands in the Carey Act segregation.

COST OF INVESTIGATIONS AND REPORT.

Following is distribution and total cost of investigations to February 1, 1916. The estimated cost of completing and printing report, 1,000 copies, is $600.

Summary of work and costs.

	January 31, 1916.	
	Paid by United States.	Paid by Oregon.
Office computations, designs, and estimates	$524.85	$650.90
Surveys	9.70	637.78
Soil examination		108.81
Total	534.55	1,397.49

DISTRIBUTION OF COSTS.

Office computations, designs, and estimates:		
Labor	$917.00	
Material and supplies	6.91	
Other expenses	251.84	
		$1,175.75
Surveys:		
Labor	523.08	
Material and supplies	4.00	
Other expenses	120.40	
		647.48
Soil examination:		
Labor	30.00	
Other expenses	78.81	
		108.81
Total		1,932.04

GENERAL DISCUSSION OF PROBLEMS AND PROJECT PROPOSED.

EXISTING WATER RIGHTS AND PROBABLE SUPPLY AVAILABLE FOR OTHER LANDS.

The records of discharge of the streams in Warner Valley from 1909–10 to 1914–15 (see "Water supply"), including as they do one year of extremely high discharge and one of extremely low discharge, with the intermediate years fairly constant, provide, when considered in connection with other streams of central Oregon, what is believed to be a very good mean of the discharge which may be expected in a much longer period. (In this connection see also "Fluctuations of the Warner Lakes" under "Water supply.") The period of record appears to cover a half cycle in the variation of volume of water in the lakes between low and high, which is also an indication that the mean discharge for the period of record is a dependable mean.

Following is a tabulation of the mean discharges to the valley from the various sources indicated for the period of record given under "Water supply."

Mean yearly inflow to Warner Valley.

Source of supply:	Acre-feet discharge.
Deep Creek	115,550
Twentymile Creek	35,000
Honey Creek	31,800
Miscellaneous inflow	13,300
Total supply	195,650

Following is a tabulation of uses made of the waters of these streams along their courses before they reach the valley, as well as in the valley itself. This information has been obtained from the report by John Dubuis for the Warner Lake Irrigation Co. A few minor changes have been made to bring the information up to date. It is to be noted, however, that the records of discharge given under "Water supply" are for the various gaging stations which, with the exception of that at Adel, are below most of the diversions made, and consequently these diversions from the upper stream are not to be deducted from the tabulated supply.

Ditches in Warner Valley, Oreg.

Name of ditch or owner.	Diverts from—	Diverts in—	Side.	Length.	Area covered.	Remarks.
				Miles.	*Acres.*	
Fitzgerald	Twentymile Creek	Sec. 35, T. 40 S., R. 23 E.			80	Above station.
Nichols	do	Sec. 25, T. 40 S., R. 23 E.			80	Do.
Warner Valley Stock Co.	do	Sec. 24, T. 40 S., R. 23 E.			(1)	Diversion to hold water right.
Small ditch	do	Sec. 24, T. 40 S., R. 23 E.	West	1½	[1] 160	
Do	do	Sec. 24, T. 40 S., R. 23 E.	East	2½	200	
Conlan ditch	do	Sec. 24, T. 41 S., R. 22 E.	Both	3	100	
Cressler	Deep Creek above Big Valley	Sec. 20, T. 40 S., R. 22 E.	do	4–5	2,000	Does not use ditches much; depends on natural flow.
Small ditch	Deep Creek	Sec. 15, T. 39 S., R. 23 E.	North	2	40	Most of water returns to creek above station.
Crump	do	SW. ¼ NE. ¼ sec. 19, T. 39 S., R. 24 E.	do		160	
Company	do	SW. ¼ NE. ¼ sec. 20, T. 39 S., R. 24 E.	do	3½	800	Covers several ranches. Diverts on south side but crosses near intake.
M. C.-Givens	do	SE. ¼ NW. ¼ sec. 20, T. 39 S., R. 24 E.	South	2	300	Covers some of Wible's, M. C., and Given's land in E. ½ NE. ¼ sec. 29, and W. ½ NW. ¼ sec. 28, T. 39, R. 24.
Wible-Mesner	do	Center, sec. 20, T. 39 S., R. 24 E.	North	1	300	Covers two ranches.
Wible ditch	do	Center, E. ½ sec. 20, T. 39 S., R. 24 E.	do		40	Extends to SW. ¼ NW. ¼ sec. 24, T. 39, R. 24.
NOTE.—All the above ditches on Deep Creek divert above the Adel station.						
M. C. Canal (Warner Valley Stock Co.).	do	SE. ¼ NW. ¼ sec. 21, T. 39 S., R. 24 E.	South		1,500	Capacity about 40 to 50 second-feet.
Small ditch	do	Below M. C.			40	All water below this goes into marsh and lake.
Morris	Camas Creek	Secs. 5 and 8, T. 39 S., R. 21 E			(1)	In Camas Prairie above reservoir site.
Barry	Mud Creek	Sec. 32, T. 38 S., R. 22 E.			80	
Loftus	Crane Creek	Crane Lake			1,000	Watered by natural overflow; whole creek used.
W. Z. Moss	Honey Creek	Sec. 23, T. 36 S., R. 22 E.				Small ditch.
Charlstrand	do	Sec. 24, T. 36 S., R. 22 E.				Do.
W. Z. Moss	do	Sec. 24, T. 36 S., R. 23 E.	North	2		No water yet diverted and no permit granted; has filed on Snyder Reservoir.
Riggs	do	Sec. 19, T. 36 S., R. 24 E.	do	1	100	Below station.
Scammeron	do	Sec. 19 or 20, T. 36 S., R. 24 E.	do	1	80	Do.
Lynch	do	Sec. 20, T. 36 S., R. 24 E.	South	½	40	Do.
7-T Ditch	do	Sec. 28, T. 36 S., R. 24 E.	Both			Diverts all water of creek by flooding swamp, area covered undetermined.
W. Z. Moss	Snyder Creek	Above gaging station				Area not determined; most of water returns.
V. Berry	Twelvemile Creek	Sec. 20, T. 37 S., R. 22 E.			200	
Allen	McDowell Creek	Sec. 2, T. 37 S., R. 22 E.			160	
Petrie	do	Sec. 14, T. 37 S., R. 22 E.			40	
Total	Twentymile Creek	Above station		3	180	
	Do	Below station		3	360	Not including Warner Valley Stock Co., undetermined.
	Deep Creek and tributaries	Above Adel station		10	[1] 4,720	Not including Morris in Camas Prairie.
	Do	Below Adel station		2	1,540	
	Honey Creek and tributaries	Above Plush station		6	[1] 400	Probably 700 to 800 in all.
	Do	Below Plush station		4	[1] 220	Not including 7-T diversion by flooding.

[1] Exact area uncertain.

In the tabulation of yearly inflows to Warner Valley the discharge of the five small ditches diverting from Deep Creek above the Adel gaging station has been included. These ditches serve the higher delta lands about the mouth of Deep Creek, and are estimated to divert about 5,000 acre-feet yearly. The lands served by them are not included in any project proposed, and this amount should be deducted from the supply available from Deep Creek, making the net mean yearly supply to the valley about 190,000 acre-feet. This amount is, therefore, the mean yearly supply available for any development proposed in the valley, including irrigation of the marsh lands, which at present divert their supply below the gaging stations from the three streams entering the valley.

DUTY OF WATER AND IRRIGATING SEASON.

PRESENT USES ON BENCH LANDS NEAR ADEL.

Five ditches, namely, the Company, M. C.–Givens, Wible–Mesner, Crump, and Wible Ditches, divert from Deep Creek above the county bridge at Adel. These ditches are constructed to serve about 1,600 acres, but the land actually served by them is estimated at 800 acres. The records of discharge (see "Water supply") indicate that the diversion made by these ditches is from 4,500 to 5,500 acre-feet, or an average of 5,000 acre-feet yearly. This would indicate a yearly use of 6.25 acre-feet per acre of land actually irrigated. It is the custom, however, to keep these ditches running part full when no irrigating is being done, partly to supply water for stock and to save the trouble of regulating the flow to suit the irrigating uses at all times. Possibly as much as 1.25 to 2.25 acre-feet is thus wasted, in so far as irrigation uses are concerned, leaving 4 to 5 acre-feet as the amount actually used on the land. The area served by these ditches is largely the old delta land formed when this area may have been under the water surface of the lake. Cuts made in road construction show deposits of gravel, and it may be said that the soil, as a rule, is quite coarse and possibly requires the 4 or 5 acre-feet of water used. A large part of the area is used for raising alfalfa, three crops being commonly cut. Orchards and gardens on the various ranches near Adel are also supplied by these ditches. During the past season there was only a small supply available for the second crop of alfalfa. The water is usually turned into the ditches from the middle to the latter part of April and the use continued until late fall for the orchards and pasture.

PRESENT USES ON MARSHLANDS.

A canal of about 40 second-feet capacity diverts from Deep Creek just below the county bridge at Adel to serve about 1,500 acres of

hay lands of the M. C. ranch. No regular system is used in irrigating this hay land. It is the common practice to place checks in the different channels and allow the water to spread out over the lands. A few dikes have been built at certain places to hold back the water in order to flood the lands above them.

There are about 3,000 acres of gently sloping hay lands where Twentymile Creek enters the valley. Much the same practice is used in watering these lands. The amount of water so used has not been determined.

In North Warner Valley similar diversions of Honey Creek have been made to water hay lands lying between Plush and Hart Lakes. About 8,000 acres of marsh lands lying north of Hart Lake, mostly a part of the 7-T ranch, slope from Hart Lake northward. The general elevation of this land is a few feet lower than the normal elevation of Hart Lake, and the tract is largely subirrigated, although two diversions from Hart Lake were noted. During the year 1915 Hart Lake did not reach an elevation permitting of water being diverted at these points, and consequently the yield of hay on this area was very much less than in former years.

RECENT INVESTIGATIONS OF DUTY OF WATER.

A comprehensive investigation of the duty of water was carried on by Don H. Bark[1] on the Snake River in Idaho during the seasons 1910 to 1913, inclusive. The investigations covered a wide scope of territory, and the experimental tracts included types of soil ranging from the finest adobe clays to coarse gravel. The elevations of the lands range from 2,100 to 4,950 feet above sea level. The experimental tracts, averaging about 15 acres, were accurately measured, and the quantity of water delivered to them as well as the waste from them was carefully measured.

The conditions as to soil, temperature, and rainfall in central Oregon are so similar to those in the higher territory investigated by Bark that the results he obtained should have a great deal of weight in determining the duty of water for this project, especially for those lands in North Warner Valley located on the slopes above the valley bottom and in the Rabbit Creek Basin. A majority of the experiments were conducted with alfalfa and grains. Following is a summary of the depths of water applied to the medium clay and sandy loam soils.

[1] Duty of Water Investigations, by Don H. Bark, irrigation engineer in charge of irrigation investigations in Idaho; Office of Experiment Station, U. S. Department of Agriculture.

Summary of depths of water applied by months to 171 fields of grain and alfalfa on medium clay and sandy loam soils in Idaho (Bark).

[Altitudes ranging from 2,400 to 5,000 feet. Seasons of 1910, 1911, 1912, and 1913.]

Season.	Plats.	April— 1-15.	April— 16-30.	May.	June.	July.	Aug.	Sept. 1-15.	Total for season.
119 fields of grain:									
1910	31			.3210	.6000	.5460	.0780		1.5450
1911	30			.0270	.6540	.4780	.0100		1.1690
1912	25				.9420	.6550	.0460		1.6430
1913	33		.0392	.2062	.5434	.5941	.2268		1.6097
Average			.0098	.1385	.6849	.5683	.0902		1.4917
Per cent of total			.66	9.28	45.91	38.10	6.05		100.0
52 fields of alfalfa:									
1910	15	.0600	.0210	.5540	.7390	.6530	.6070	.0650	2.6990
1911	13		.0350	.4930	.2930	.9130	.6970	.2480	2.6790
1912	11			.4910	.5030	.6210	.6080	.0380	2.2610
1913	13			.8627	.2284	.7422	.3854	.0175	2.2362
Average		.0150	.0140	.6002	.4408	.7323	.5744	.0921	2.4688
Per cent of total		.61	.57	24.31	17.86	29.66	23.26	3.73	100.0

As a result of Bark's investigation of the comparative amounts of land under cultivation for the two types of crops—that is, hay and pasture, requiring higher duty of water, and grain, potatoes, and orchards, requiring the lower duty—he concludes it is fair to assume that any normal project in southern Idaho will ultimately be developed to about equal areas of the two classes mentioned, and so takes for the economic duty of the entire irrigable area an average of the duties found for grains and alfalfa on the medium or average soils. The results by months are as follows:

Average duty for a normal project in southern Idaho (Bark).

	April.	May.	June.	July.	August.	September.	Total season.
Duty in acre-feet	0.0194	0.3693	0.5628	0.6504	0.3323	0.0460	1.9802
Per cent of total	0.98	18.65	28.42	32.85	16.78	2.32	100

In Bulletin No. 119 of Oregon Agricultural College Experiment Station[1] may be found the results of the experiments carried on during the season of 1912 at Redmond under the supervision of Prof. W. L. Powers, in charge of irrigation and drainage work of the Oregon Experiment Station, who acted as superintendent in direct charge of the Redmond work in 1912. This bulletin should be read in conjunction with this report.

[1] A report of the Experimental and Demonstration Work on the Substation Farms at Moro, Burns, Redmond, and Metolius, by H. D. Scudder, 1914.

43920—16——5

FINDINGS OF THE STATE WATER BOARD OF OREGON WITH RESPECT TO DUTY OF WATER ON MARSHLANDS.

During the summer of 1915 the State water board of Oregon took evidence relating to the use of water of Chewaucan River in order to make an adjudication of the waters of that stream. Following is an abstract of their findings:

From the testimony, evidence, maps, exhibits, and other data filed in this cause, including the maps and information furnished by the State engineer and a personal inspection of conditions on the ground by all the members of the State water board, the following facts are found relative to the character of soil, kinds of crop, climate, evaporation, alkali, reclamation system, duty of water, and water supply.

Character of soil.—The soils for the purpose of this adjudication may be divided into two classes, namely, marshlands and uplands.

The marshlands comprise all lands embraced within the upper and lower Chewaucan Marsh, or approximately 22,135 acres.

The uplands comprise all other lands irrigated or to be irrigated from the Chewaucan River or its tributaries outside the limits of the marsh. The water requirements of these two types of soil are different.

The marshland is a rich, peaty soil of fine texture from 0.5 to 2.5 feet in depth, generally free from alkali and of high water-holding capacity. This surface soil is underlaid by a comparatively impervious stratum of whitish earth of unknown depth. During the nonirrigation season the surface soil dries out a few inches in depth, forming a fine spongy mulch, which largely prevents further evaporation, thus lessening materially the amount of water required the following year to bring the soil to a proper moisture capacity for plant growth. At a few places where little or no surface vegetation is found the surface soil shrinks and cracks on drying, giving indications that the soil is bone dry to great depth. Such appears not to be the case. The surface of the marsh is comparatively flat, sloping to the southeast approximately 1 foot to the mile. It subdrains with difficulty, if at all, under present conditions.

The uplands are in general the usual volcanic ash soil typical of eastern Oregon and Idaho, with more or less clay, sand, gravel, and loam intermingled. They are generally steeper than the marshland and will require a somewhat greater amount of water for their proper irrigation.

Kinds of crop.—A considerable portion of the marsh produces a wild grass, intermingled with tules and flags. It is cut annually and used for hay. Portions of the marsh inadequately drained produce rank growths of tules and flags, with little, if any, marsh grasses of commercial value intermingled. The sugar grass and other hay-making grasses do not require water standing or moving over the surface of the ground, but appear to do best when the moisture capacity of the soil is something less than complete saturation. There is evidence to show that sugar grass of apparently good stand and quality is found on canal banks where no water is applied on the surface, the necessary moisture being supplied entirely by capillary action of the soil. Standing or moving water on the surface is therefore not essential to plant growth.

On the uplands all of the grains, grasses, and hardy fruits and vegetables which are ordinarily produced at such elevation and in such climate are grown.

Climate.—The average elevation of the marsh is approximately 4,400 feet. The climate is therefore peculiar to this elevation. During January, February, and March the mean temperature at Paisley is under 41° F., as shown by the

United States Weather Bureau records. This is below that necessary to produce plant growth. For April it is 47°, and increases gradually to 67° in July, diminishing to 55° in September.

The mean annual precipitation at Paisley is practically 12 inches. Of this, 4.14 inches fall during the crop-growing months, April, May, June, and July. During the first three months of the year 3.47 inches fall, and during the last three months 2.9 inches, making a total of 6.37 inches. During the six winter months evaporation is at its minimum, and the moisture in the soil due to this precipitation should be sufficient to start plant growing in the spring without immediate application of water. But little, if any, water should therefore be allowed for saturation of the soil.

Evaporation.—There being no necessity for standing water on the surface, the figures for evaporation from a water surface can not be used in computing duty of water. The formation of a loose mulch on the surface of the peaty soils of the marsh during dry weather indicates that losses by surface evaporation are small and probably less than for the uplands.

Reclamation system.—The marshlands are not completely drained, nor is the irrigation system adequate for the most economical use of water thereof. For 3 years out of 11 for which records are available the entire flow of the stream is inadequate to supply the marsh and uplands in the vicinity of Paisley. A dredge is now at work on the marsh looking to an improvement of the present system so as to meet this limitation on water supply imposed by nature. Though the marshlands are comparatively flat and well adapted to irrigation by flooding, yet few, if any, checks have been thrown up to divide the land into basins of reasonable area. For many miles at a stretch no gates are found in the canals to turn water out. Water is applied at the upper end of the marsh in great quantities and allowed to find its way slowly over the marsh as best it may to the lower end. Some parts receive too much, others too little, water. During years of extreme floods damage is done by washing out headgates, overflowing canal banks, and flooding the marsh unnecessarily.

The uplands are irrigated by ditches according to the usual practice in such districts.

Alkali.—The rich, peaty soil on the surface of the marsh is in general free from alkali. United States Geological Survey analyses of Chewaucan River waters show that they are "excellent for irrigation purposes and could be used almost indefinitely without causing injurious accumulation of alkali because of the dissolved matter in them." The maintenance of a sheet of water moving over the surface to remove alkali is therefore unnecessary. Furthermore, it appears from standard works that alkali when dissolved would sink into the soil and only pure water run off. The remedy for alkali is rather removing excess irrigation water and provision for drainage.

Allowable waste.—Theoretically, no irrigation water should be allowed to waste off the lower end of the field. That is considered by some impractical. The waste from the upper basins or upper marsh can be caught up and used on the lower basins and lower marsh. An allowance of 12½ per cent of the water allowed for one-fourth the area appears to be reasonable.

Duty of water.—Measurements of Chewaucan River above Paisley, at The Narrows, and at Hotchkiss Ford, indicate by proper deductions the amount of water actually used or consumed on the intervening lands.

Thirty-one thousand three hundred and ninety acre-feet were consumed between the upper two gauges on 20,538 acres of land, or 1.52 acre-feet per acre for the irrigation season, January 19 to July 1, 1914. On the 7,792 acres embraced in the lower marsh, 10,760 acre-feet were consumed during the same

period, or 1.38 acre-feet per acre. On the total area of 28,330 acres, which includes some uplands, substantially 1.5 acre-feet per acre were actually consumed. This figure is arrived at by measuring the water which flows on a given tract and deducting that which wastes off the lower end, which is the usual method of determining the duty of water. But in practice some water is generally allowed to waste off. While 12½ per cent of the water allowed for one-fourth the marsh area is a sufficient allowance for waste, yet, due to the inadequacy of the present drainage and irrigation system, the board feels that at least 25 per cent of the above amount of water may be allowed, at least temporarily while the system is being perfected, and accordingly 2 acre-feet per acre of water from Chewaucan River should be allowed for the marshlands, during an irrigation season, March 1 to July 15 of each year. The precipitation of 12 inches per annum, together with drainage from the uplands adjoining which must flow into the marsh, makes this appear a liberal allowance.

The uplands being somewhat steeper and not so favorably located as to impervious substrata to prevent deep percolation, will require more water than the marshlands, and 3 acre-feet per acre diverted from the stream during an irrigation season commencing April 1 and ending September 1 of each year is an ample allowance. For the lands of the Portland Irrigation Co. embraced in the Carey Act project, to be supplied largely by the storage of excessive floods, 2 acre-feet per acre delivered on the land is required, and an ample storage reservoir of such capacity as will insure the carrying over of such amount of water from wet years and delivery in dry years should be provided.

For domestic and stock water, the marshlands should not have delivered from Chewaucan River to exceed 20 second-feet during the months of December, January, and February, when freezing weather prevails, and 10 second-feet during the balance of the nonirrigating season. During the irrigation season the allowance for irrigation on both marsh and uplands is ample for stock and domestic purposes.

That to facilitate distribution of the waters of Chewaucan River and its tributaries in accordance with the above limitations as to volume, no diversion should be made at a rate in excess of one-fourth of 1 cubic foot per second of time for each acre, and for such period when water is available and will not exceed the above limitations as to volume.

RELATION OF WATER DUTY TO DRAINAGE.

It has been the general experience throughout the West that a liberal use of water in irrigating has resulted in damage to lower lands by bringing the alkalies and other harmful salts to the surface. This has led to the necessity for greater expenditures than anticipated in constructing drainage canals and in other ways guarding against the trouble. Hence it may readily be seen that the duty of water should be kept as near as may be to actual needs of crops, and care taken in applying only such an amount at each irrigation as can be absorbed in the ground and used by the plants. There is an unavoidable loss from deep percolation, and this water returning to the surface at some lower point is the cause of much damage. Application of too much water at one time tends to increase this loss by deep percolation, and should be avoided just as far as possible.

DUTY ASSUMED FOR PROJECT PROPOSED.

The main features entering into the determination of the duty of water to be assumed for this report are the classes of soil, the possible effect of the use of a large quantity of water on the marsh lands, and the supply available.

In the first instance the lands in North Warner Valley which are not marsh lands will have to be served largely by pumping, and consequently the duty of water for these lands should not in any case be in excess of the amount which will give the best yields and should probably be somewhat less than this amount. The close texture of the soils in the marsh lands to be reclaimed will probably require a duty of not to exceed 1½ acre-feet of water per acre on the land. The use of even this amount of water will most certainly necessitate well-planned drainage. The danger of bringing alkali to the surface of the soil by the application of too much water on these lands is a very important consideration.

The area of land in the valley suitable for irrigation is probably not over 80,000 acres. The water supply available for this land has been shown to be about 190,000 acre-feet yearly, or a supply at diversion of about 2.37 acre-feet per acre. The use of this entire mean supply, if not harmful to certain sections of the area, would be advisable from the standpoint of avoiding possible flooding during a period of run-off in excess of the normal. It is thought that the use of water on the marshlands to be reclaimed should not be in excess of 2 acre-feet per acre, even with good drainage provided. The lands to which water must be pumped could possibly use 2½ to 3 acre-feet, but this would not be advisable on account of the cost of pumping.

In arriving at a definite duty of water for this report the following assumptions are made, conditional on thorough drainage for the marshlands and careful preparation of the higher lands for irrigation. The allowance for grain crops should be 1 acre-foot per acre delivered to the land, and for hay and alfalfa crops 2 acre-feet per acre. The amount of land used for the cultivation of the two classes of crops will probably be about equally divided.

The duty of water should be allowed to the entire irrigable acreage on any farm, so that the irrigator if he wishes may use every available acre. The duty assumed for this report on the above assumptions is 1.5 acre-feet per acre of irrigable land delivered to the farm unit, distributed through the irrigating season as follows: May, 28 per cent; June, 35 per cent; July, 30 per cent; and August, 7 per cent.

SEEPAGE AND EVAPORATION LOSSES.

Seepage and evaporation are the chief losses, accounting for the difference between the water supply and the amount actually used in

irrigating. Other losses which occur are waste or leakage caused by breaks in canals, faulty structures, such as head gates, turnouts, wasteways, and drops. These losses may be almost entirely eliminated by good construction.

Considerable study has been made of seepage and evaporation losses from reservoirs and canals in connection with the present Oregon cooperative work. The results may be found in the Deschutes, Ochoco, Silver Lake, and John Day project reports, and will not be repeated here. Evaporation losses from canals are practically negligible, and such losses are usually included in the seepage losses, which may be anywhere from 6 inches to 3 feet or more in depth from the wetted area of canals each 24 hours. The smaller losses occur in comparatively tight soils such as the clay and clay loam soils, while the larger losses occur in coarse sandy soils. The estimates of losses in canals and laterals for this report are based on computations made for the Silver Lake project report, where a loss of 1 foot in depth per day from the wetted area of canals was used.

The soils in Warner Valley are much the same, with the exception that the marsh and bordering areas below the medium sandy soils are of a more clayey nature and the losses will be, if anything, less than in the proposed Silver Lake project.

Evaporation plays an important part in the consideration of the reclamation of marshlands in Warner Valley, where great volumes of water will have to be disposed of in the sump lakes and in Coleman Valley waste reservoir in years of abnormal run-off.

Lakes.—The past year was favorable for obtaining a record of evaporation on Flagstaff Lake and lakes of that vicinity. See "Evaporation" under "Water supply."

The gross evaporation for the year is estimated by Fred F. Henshaw to be 3.9 feet from the surface of these lakes, and the evaporation in excess of precipitation 3.3 feet for the year. This rate of evaporation is used throughout this report in studying the wasting capacity of the lakes. See "Necessity of flood control for reclamation of marshlands."

Reservoirs.—The gross evaporation at Big Valley, located about 900 feet higher than the lakes and near the high mountains, is probably somewhat less than 3.9 feet and may be as little as 3 feet per year. In this estimate the gross evaporation from Big Valley Reservoir is taken at 3.5 feet, and the probable precipitation 1.5 feet, leaving an estimated evaporation of 2 feet in excess of precipitation. Cowhead Lake, located at a lower elevation and farther down the high mountains, probably has a greater evaporation than Big Valley Reservoir, and the evaporation in excess of precipitation, indicating the net loss which may be expected from the lake surface, is taken at 2.5 feet per year.

NECESSITY OF FLOOD CONTROL FOR RECLAMATION OF MARSHLANDS.

It is at once apparent that any scheme for the reclamation of the marshlands in Warner Valley must provide for the disposition of all the water entering it by use on the lands and by evaporation from the surface of the lakes in the valley and reservoirs which may be required along the courses of the various streams entering the valley.

There is a possibility of disposing of some of the present inflow by allowing the storage development at Cowhead Lake and diversion at Twelvemile, Rock, and Keno Creeks into this reservoir for use in the Surprise Valley, in California, as outlined under "Reservoir sites." The amount so taken from the present flow of Twentymile Creek would probably not exceed 20,000 acre-feet in mean years.

High-water marks found on the shore of Crump Lake show that in years of high run-off the water stands from 1 to 3 feet in depth over the marsh area in that part of the valley before a sufficient volume can find its way to Hart Lake to balance the inflow from Deep Creek and Twentymile Creek. A deep dredged channel connecting Hart Lake with Crump Lake and Crump Lake with Twentymile Creek would give the required drainage for the marshlands in South Warner Valley. A dredged channel from Hart Lake to Flagstaff Lake would also be required to keep Hart Lake about 2 feet below its present normal elevation and make possible the reclamation of marshlands bordering it. Immediately to the north of Hart Lake the ground elevation drops about 4 feet below the normal elevation of the lake, and the total drop from Hart Lake to Flagstaff Lake is about 8 feet. The general elevation of Flagstaff Lake and lakes in its vicinity compared with that of Bluejoint Lake is about the same, there being a slight fall toward the north. This is probably due to the fact that each lake receives its inflow from the next lake to the south when that lake is full to the overflow point. Shallow, winding channels usually connect these lakes. The most recent high-water marks along their shores are those of 1910, and show that Flagstaff Lake reached an elevation about 3½ feet higher than that reached by Bluejoint Lake before they began to recede. Practically all of the low lands around Anderson and Mugwump Lakes must have been under from 1 to 3 feet of water at this time. Had these lower lakes been connected by channels about 8 to 10 feet deep this condition would have been relieved, as Flagstaff Lake would have been at least 2 feet lower. The necessity of connecting these lakes by dredged channels is therefore seen, not only in order to relieve high-water stages in years like 1910, but to increase the evaporating area of these lakes, which must receive and evaporate all excess waters in ordinary years.

Following is the estimated storage capacity of all the lakes in the valley to elevations indicated, which are such as would not cause flooding or damage to the marshlands north of Hart Lake and which would insure the reclamation of all marshlands around Hart Lake and in South Warner Valley:

Approximate storage capacity of lakes in Warner Valley.

	Acre-feet.
Crump Lake, 2 feet below normal elevation	8,000
Hart Lake, 3 feet below normal elevation	28,000
Flagstaff Lake, to a depth of 8 feet	30,000
Bluejoint Lake and lakes between it and Flagstaff Lake (8 to 10 feet depth)	155,000
Total storage capacity	221,000

The water surface exposed in these lakes to be used as reservoirs and evaporating areas is about 32,000 acres. In years such as 1910, when it is estimated 270,000 acre-feet entered the valley before the lakes reached their high stages and probably prior to May 1, very little evaporation would be expected to occur before such high stage. Probably not more than 6 inches in excess of precipitation would be evaporated in this 32,000 acres before high stage, or 16,000 acre-feet. The lakes, on this assumption, would take care of 221,000 acre-feet storage capacity and 16,000 acre-feet evaporation, or a total of 237,000 acre-feet. There would thus have been required in 1910 33,000 acre-feet storage capacity on the streams entering the valley, to protect the lands north of Hart Lake, on the assumption, however, that the sump lakes, Bluejoint and Flagstaff, were so connected by dredged channels as to make them practically one lake.

It is certain that greater volumes of early spring run-off may be expected to occur in an occasional year than in this year of highest measured inflow. Old high-water marks were found by J. E. Stuart, of the United States Geological Survey, in 1914, which he determined by level to be 7.3 feet higher at Flagstaff Lake and 10.7 feet higher at Bluejoint Lake than the high-water marks of 1910. (See "Fluctuations of the Warner Lakes" under "Water supply.")

It is largely a matter of speculation as to whether the lakes attained this enormous volume from a single spring run-off or from a period of several years of abnormal discharges into the valley. An estimate made of the probable volume in the lakes at this extremely high stage, based on all the topography and information available, shows it to have been about 715,000 acre-feet. If the volume of water in the lakes for the preceding year had been about the normal amount, estimated to be 140,000 acre-feet, the inflow during a single season up to the high stage must have been 575,000 acre-feet, and

probably 620,000 acre-feet for the seasonal year. However, it seems more probable that this increase in volume in the lakes was the result of two or more seasons of high run-off. (See "Volume curve" under "Fluctuations of the Warner Lakes.")

The estimated discharge of 308,000 acre-feet for the seasonal year 1909–10 is only 57 per cent in excess of the mean discharge into Warner Valley for the six-year period of record, 1909–10 to 1914–15, which mean is probably a dependable one for a much longer period. A study of other streams in central Oregon on which records have been kept for longer periods reveals maximum discharges over 100 per cent in excess of the normal discharges of those streams, Chewaucan River having a discharge in 1906–7 of 66 per cent above normal for a period of record of 10 years, Silvies River and Malheur River in Malheur Valley having discharges in 1903–4 of 117 per cent and 110 per cent in excess of their normal discharge during 10 years of record. If we assume, then, that in a 10-year period a discharge into Warner Valley 120 per cent in excess of the normal discharge of 195,000 acre-feet may be expected, such discharge would be 440,000 acre-feet. For a longer period, however, a quantity even greater than this may be expected.

It is estimated that 1,200,000 acres are included in the drainage area tributary to Warner Valley. Nearly all of the territory producing the run-off to the valley is included within 600 square miles, or 384,000 acres, drained by the three streams entering the valley, this area being largely timbered and lying on the mountain slopes to the west and southwest of the valley.

In the seasonal year 1909–10 the measured and partly estimated discharge of the three streams was 270,000 acre-feet, or a mean run-off of 8½ inches from the 384,000 acres drained. The partly estimated discharge from other sources (see "Miscellaneous inflow" under "Water supply") was 38,000 acre-feet, or a mean run-off of half an inch for the remaining 816,000 acres of bare table-land and rim rock. In ordinary years the run-off from the stream-drained areas is estimated to be 6 inches, and an inappreciable amount from the other area.

The extreme run-off which might be expected would follow, first, conditions favorable to rapid melting of a heavy winter snowfall, perhaps by warm rains in the spring; and second, fall conditions which would make a wet frozen ground surface, such as alternating rains and freezing weather. With such a condition possible, it is thought the run-off from the 816,000 acres might reach 4 inches and produce a run-off of 270,000 acre-feet, while the mean run-off of 6 inches from the stream area might be increased to 10 inches, producing from the 384,000 acres 320,000 acre-feet, or a total run-off of

590,000 acre-feet to the valley in such extreme year. Nine-tenths of this amount, or 531,000 acre-feet, would probably come before high stage in the lakes would be reached.

With the possibility of storing and evaporating 237,000 acre-feet in the lakes before high-water stage is reached, there would be required 294,000 acre-feet storage on the streams entering the valley, if the lands north of Hart Lake are to be made safe from flooding at all times. Little evaporation could be counted on to take place from the surface of reservoirs before such high stage would be reached, especially in years of such extreme run-off, when the precipitation would undoubtedly be abnormal. The development of this amount of storage is impracticable, so that the lands north of Hart Lake would have to be left subject to a flooding of from 1 to 3 feet for a short time during high-water stages in such a year as might be expected once in probably 25 to 50 years.

The volume of water possible to store in Bluejoint and Flagstaff Lakes, together with those between them, with surfaces reaching to an elevation 2 feet higher than shown in the above tabulation, is estimated to be 262,000 acre-feet, which with the 38,000 acre-feet in Crump and Hart Lakes would make 300,000 acre-feet, and possibly evaporate 20,000 acre-feet more before high stage. With this stage of water permissible and assuming still to reclaim all marsh lands west of Hart Lake and in South Warner Valley, 210,000 acre-feet storage would be required on the streams entering Warner Valley in the possible event of a year coming when the inflow to high stage might reach 530,000 acre-feet.

The records of run-off from Big Valley on Deep Creek indicate that in a year of such extreme run-off the flow from Big Valley might be expected to reach or exceed 100,000 acre-feet. The storage capacity for this amount can be obtained at a moderate cost, and such development is advisable from the standpoint of reclaiming the marshlands, although the mean yearly run-off from Big Valley is only a little more than 50,000 acre-feet. Coleman Valley can be utilized for 60,000 acre-feet storage without pumping, and with an estimated feasible storage capacity of 75,000 acre-feet for Cowhead Lake, in conjunction with irrigation development in the Surprise Valley, there could be had at the three sites storage for 235,000 acre-feet available for holding back this amount in years of extreme high run-off. The Mud-Camas Reservoir site, developed in conjunction with possible future requirements, would be of value in making more certain the protection of the lands north of Hart Lake.

Following is a tabulation of the mean yearly use and waste of water in Warner Valley, based on the proposed development, outlined under "Proposed project:"

Estimated possible mean yearly use and waste of water—proposed project.

		Acre-feet.
Seepage, Big Valley, 10 per cent of 50,000 acre-feet		5,000
Evaporation, Big Valley, 2 feet net on 2,000 acres		4,000
Evaporation, Coleman Valley, 3.3 feet net on 5,000 acres		16,500
Evaporation, Warner Lakes, 3.3 feet net on 32,000 acres		105,500
Use, present use on lands near Adel		5,000
Proposed project, 60,000 acres, at 2 acre-feet	120,000	
Possible return seepage	20,000	
Net use		100,000
Total use, seepage, and evaporation		236,000

With the estimated mean yearly inflow of 175,000 acre-feet it will at once be evident, following Cowhead Lake storage development, that the sump lakes in the north end of the valley will be dry at the close of each season when the inflow does not exceed 235,000 acre-feet, and the reservoirs will be empty, thus keeping conditions favorable for handling the water in a year or years of greater discharge.

Following is a tabulation of the estimated possible storage use and waste in a year of extremely high run-off. Cowhead Lake storage is included, as the estimated possible flood conditions already outlined include discharge from the area which would be naturally tributary to Cowhead Lake and the area drained by the streams which it is proposed to divert thereto.

Estimated possible storage use and waste in a year of flood run-off.

		Acre-feet.
Seepage, Big Valley, 10 per cent of 100,000 acre-feet		10,000
Evaporation, Big Valley, 2 feet net on 3,000 acres		6,000
Coleman Valley, 3.3 feet net on 5,000 acres		16,500
Warner Lakes, 3.3 feet net on 38,000 acres		125,000
Use, present use on lands near Adel		5,000
Net use, proposed development		100,000
Storage hold-over:		
Big Valley	100,000	
Coleman Valley	60,000	
Cowhead Lake	75,000	
		235,000
Total storage, use, and waste		497,500

Following a year of extreme run-off, estimated to amount to 590,000 acre-feet, there would probably be left in the sump lakes about 82,500 acre-feet at the beginning of the following season, with the reservoirs practically full. The available capacity in the sump lakes to receive the additional seasonal inflow would then be 300,000 acre-feet less 82,500, or 217,500 acre-feet. With the estimated use of 105,000 acre-feet and seepage and evaporation losses of 157,500

acre-feet, as tabulated above, 480,000 acre-feet could be handled the following year without raising the water in the sump lakes to within 2 feet of the permissible elevation in Hart Lake. In other words, a year of extremely high run-off might be followed by a year having a run-off as great as 480,000 acre-feet without causing any more serious flood conditions than in the extreme year.

Effect of extended use of water in North Warner Valley.—It appears from the foregoing discussion that the irrigation use will not have much effect on the question of handling the water, nearly all of which may be expected to enter the valley before the irrigating season begins in a year of extreme run-off. However, it is evident that an increased use during the irrigating season will draw down the stored water and to this extent relieve the situation for the following year. There is approximately 12,000 acres in Rabbit Creek Basin and possibly 8,000 acres in the extreme north end of Warner Valley, or a total of 20,000 acres, which may be eventually served by pumping. The Rabbit Creek Basin lands are of somewhat doubtful value on account of the character of the soil, and would require a 120-foot pumping lift. They have therefore been omitted from the proposed project, not necessarily as infeasible for irrigation development, but as not sufficiently attractive to include in the proposed project for first development.

The 8,000 acres in the north end of the valley would require a long feed canal from the proposed Flagstaff pumping plant, kept well above the possible flood line of the sump lakes, as under the proposed development the water in Bluejoint Lake and other lakes below Flagstaff Lake would probably become too alkaline for use and would not, therefore, be suitable for direct pumping. This additional 20,000 acres would require about 40,000 acre-feet at diversion yearly and bring the estimated yearly use up to 165,000 acre-feet for the ultimate development in the valley.

Effect on proposed Warner Valley project of proposed Cowhead Lake storage development for use in Surprise Valley.—The proposed plans of the Modoc County Irrigation Co. for use of waters stored in Cowhead Lake and diverted thereto from tributaries of Twentymile Creek have been outlined and discussed from the standpoint of physical possibilities under "Reservoir sites." It was estimated that such development would probably result in a mean yearly loss to Twentymile Creek of about 20,000 acre-feet. This would probably not exceed 10,000 acre-feet in a year in which this water would actually be needed in Warner Valley.

It is thought that in a year of extremely high run-off this development might result in holding back from Warner Valley possibly as much as 75,000 acre-feet.

The question of whether the proposed diversions to Cowhead Lake and the use of the water so stored in Surprise Valley would be beneficial to the proposed development in Warner Valley is one of balancing the advantage of holding back from Warner Valley large volumes of water in years of high run-off against the value of a relatively small amount of water to Warner Valley in years of low run-off. The estimated inflow to Warner Valley during the past year indicates about a 50 per cent shortage under the proposed plans. With the proposed Cowhead Lake development for Surprise Valley lands, it is thought this shortage, by reason of the probable diversions, would be increased to about 55 per cent, which would not be serious under the assumptions of 2 acre-feet per acre required at diversion for Warner Valley lands. However, it is evident that permission to divert any waters from streams in Oregon to Cowhead Lake, if deemed advisable after more detailed information is secured, should be contingent on ample storage being provided in Cowhead Lake to hold back from Twentymile Creek practically the entire amount of water which would otherwise enter it in years of maximum discharge. Diversion canals should also be required of ample capacity for handling a large proportion of the water passing such diversions in a year of great discharge.

PROPOSED PROJECT.

It is proposed:

First. To provide storage in Big Valley for about 100,000 acre-feet by constructing a dam 50 feet high in the narrow outlet of the valley.

Second. To construct a power plant just below the Deep Creek Falls to develop 2,000 electrical horsepower for pumping to serve 27,000 acres of land in North Warner Valley.

Third. To construct a main drainage channel from Flagstaff Lake through Hart and Crump Lakes to the mouth of Twentymile Creek, with a branch channel to Deep Creek and main drainage laterals in South Warner Valley, as required to serve the farm drainage systems.

Fourth. To connect the lakes below Flagstaff Lake with Bluejoint Lake by dredged channels in order to increase the evaporating area for disposal of excess water in years when there will be waste.

Fifth. To serve 33,000 acres of land in South Warner Valley by gravity canals diverting from Deep Creek.

Sixth. To pump water from Hart Lake for irrigation of 21,000 acres of land lying west and north of that lake.

Seventh. To pump from Flagstaff Lake for the irrigation of about 6,000 acres northwest of Flagstaff Lake and the adjacent lakes below it.

The proposed project requires three main canals in South Warner Valley diverting from Deep Creek at the edge of the valley. No diversion of Twentymile Creek is planned, as no feasible storage applicable to lands in Oregon is to be had on this stream, and the late summer flow is very small.

The East Canal will divert from Deep Creek in the SW¼ of sec. 22, T. 39 S., R. 24 E., about a mile east of Adel. This canal will be carried due east, will cross the main drainage canal at the southeast corner of section 23, and will continue about 1 mile farther east, where it will divide. From this point a branch canal will lead southeasterly for about 2½ miles to the entrance of the outlet from Coleman Valley. The capacity of the East Canal from the beginning to this junction, and of this branch canal to Coleman Valley, will be about 350 second-feet. It will be operated before the irrigating season to conduct waters which it may be desirable to waste in Coleman Valley. The length of this waste canal is 9.5 miles, 3.4 miles of which will be formed by the present dry lakes. No excavation is required, as the lake beds are 1.5 and 3.5 feet below the water grade as planned for the canal. From the junction point mentioned, the East Canal will run northward about 12 miles along the east side of South Warner Valley to about the north line of T. 38 S., the capacity diminishing from about 250 second-feet at the junction point to 40 second-feet. The area of lands to be irrigated by this East Canal is 17,500 acres. The necessary gradient for the East Canal to reach the east side of the valley and follow along the foot of the rim will be secured by building the canal partly in fill across the low portion of the valley, the water line being 3 feet above ground surface at its crossing with the drainage channel.

The South Canal will divert from Deep Creek near the southwest corner of sec. 22 in T. 39 S., R. 24 E., and will be led southeasterly to a rim rock point in sec. 20, T. 40 S., R. 24 E. It will cross the main drainage channel just before reaching this point. This canal as planned is 7.2 miles long, with a capacity at diversion of 142 second feet, and will serve 8,500 acres.

The Warner Canal will divert from Deep Creek at about the present diversion point of the "M. C." Canal, just below the county bridge near Adel, will follow around the west side of the valley toward Warner Lake post office, cross Twentymile Creek, and follow the south side of the valley to about the southwest corner of sec. 15, T. 40 S., R. 24 E. This canal will be 15 miles long, with a capacity of 120 second feet at diversion, and will serve 7,000 acres of land.

In North Warner Valley the main pumping plant from Hart Lake will be located on the west shore of the lake a mile north and about 2 miles east of Plush. This plant will lift water about 6 feet

above the normal elevation of the lake, the distribution being by a canal running northward to serve about 10,000 acres of land lying north of Hart Lake. Another canal from this pumping plant will run southwesterly to serve approximately 3,000 acres of meadow lands lying between the canal and the south end of Hart Lake.

A second pumping plant, located about a mile south of Plush, at the foot of the steep rim rock, will pump water from the last mentioned canal to a high line canal, which will run northward about 50 feet above the elevation of the lake and just above the town of Plush, to a point about 2 miles north of the north line of T. 36 S., R. 24 E. The area to be served by this high line canal is 6,000 acres.

A third pumping plant, located near the present outlet of Hart Lake, will lift water about 40 feet, and a canal will run north at this elevation as far as Anderson Lake to water 2,000 acres of the sloping lands on the east side of the valley, lying between this canal and the drainage canal which will follow the overflow channel from Hart Lake to Anderson Lake.

A fourth pumping plant to serve 6,000 acres northwest of Flagstaff Lake and adjacent lakes below it will be located in sec. 24, T. 34 S., R. 24 E., about a mile from the northwest end of Flagstaff Lake, with which the pumping plant will be connected by a drainage channel.

The total area to be served by gravity distribution in South Warner Valley and by pumping in North Warner Valley is 60,000 acres.

STORAGE REQUIREMENTS.

The proposed project to irrigate 33,000 acres in South Warner Valley and 27,000 acres in North Warner Valley, with an estimated duty at diversion of 2 acre-feet per acre, to allow a 25 per cent loss in distribution, delivered as proposed under "Duty assumed for project proposed," will require the following amounts during the four months of the irrigating season assumed:

Water requirements at diversion points, proposed project.

Month.	Per cent of total.	South Warner Valley.	North Warner Valley.	Total project.
		Acre-feet.	*Acre-feet.*	*Acre-feet.*
May	28	18,480	15,120	33,600
June	35	23,100	18,900	42,000
July	30	19,800	16,200	36,000
August	7	4,620	3,780	8,400
Total	100	66,000	54,000	120,000

It is proposed to use Crump Lake and Hart Lake as storage reservoirs below any elevation high enough to subject the surrounding lands to risk of damage. The estimated capacity of these two lakes is 6,000 acre-feet and 25,000 acre-feet, respectively.

The fact that these two reservoir sites are intermediate between the North and South Warner Valley lands necessitates separate consideration of the storage requirements of the two parts of the valley. Following is the mean monthly inflow to South Warner Valley from Deep Creek and Twentymile Creek during the proposed irrigating season, without storage, based on the average of the years 1911 to 1914, inclusive. These years are used because the monthly discharges are more typical of conditions to be expected, and the mean yearly discharge for the period is almost identical with that for the six years of record, 1910 to 1915, inclusive. While the total inflow is shown to be about 5,000 acre-feet in excess of the required amount in South Warner Valley, and May and June run-off is somewhat in excess of the requirements, July and August show a shortage of 18,860 acre-feet, requiring storage from the earlier part of the season when there is an excess.

Mean inflow to South Warner Valley and irrigation use proposed.

	May.	June.	July.	August.	Total.
	Acre-feet.	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*
Deep Creek	35,300	21,200	3,860	600	60,960
Twentymile Creek	4,980	4,360	860	240	10,440
Total	40,280	25,560	4,720	840	71,400
Use required	18,480	23,100	19,800	4,620	66,000
Surplus	21,800	2,460			24,260
Deficiency			15,080	3,780	18,860

In some years the run-off may come a month earlier, in which case the storage required would be at least 20,000 acre-feet more, or 38,000 acre-feet.

In considering the storage requirements for the lands to be served by pumping from Hart Lake and the lakes of the Flagstaff Lake district, it is assumed that Crump Lake and Hart Lake will have 31,000 acre-feet available at the beginning of the irrigating season. The 21,000 acres to be served from Hart Lake will require 42,000 acre-feet, or an excess of 11,000 acre-feet, which would have to come from direct flow of Honey Creek during the irrigating season or be allowed to pass through the drainage canals from South Warner Valley from storage on Deep Creek. The mean discharge for Honey Creek in the years 1911–1914 is 8,200, 4,200, 950, and 300 acre-feet during the months May to August, inclusive, or a total of 13,650 acre-feet, which would indicate that no additional storage is required under the proposed plan other than that in the bottom of Crump and Hart Lakes. However, should the Honey Creek run-off come one month earlier than this mean, as it did in 1910, there would be a shortage of about 6,000 acre-feet.

It appears, therefore, that the storage supply required on the upper streams should be not less than 38,000 acre-feet for the lands in South Warner Valley and 6,000 acre-feet in North Warner Valley, or 44,000 acre-feet in all. It has been shown that this storage supply can be provided most cheaply in Big Valley Reservoir on Deep Creek.

DRAINAGE.

Practically all of the lands in South Warner Valley, and about 13,000 acres of those in North Warner Valley, will require drainage on account of topography and character of soil. These lands lie at an elevation ranging from that of the lakes to but a few feet higher.

The capacity of the main drainage canals will not be determined by the amount of drainage water which will have to be removed from these lands on account of irrigation, but rather by the large volume of water which may be expected to enter South Warner Valley from Deep Creek and Twentymile Creek. These waters will have to be conducted to the sump lakes in the north end of Warner Valley through the main drainage channels.

The proposed drainage system will consist of a main drainage channel from Flagstaff Lake through Hart Lake to Crump Lake, continuing south through the lowest part of the marsh lands to the mouth of Twentymile Creek. From Hart Lake to Crump Lake the drainage channel will pass through the narrow outlet dividing the valley into North and South Warner Valleys. This portion of the drainage channel will necessarily have to be of sufficient capacity to take care of the spring run-off into South Warner Valley from Deep Creek and Twentymile Creek.

The maximum discharge of Deep Creek for the six-year period of record (see "Discharge records") may be expected to come during March, April, or May, while that from Twentymile Creek may be expected during March, the only exception during the six years being in the spring of 1911, when the maximum discharge was in April. Considering Deep Creek alone, the maximum monthly discharge of record came in May of 1912, when it was 55,000 acre-feet. However, during this month the discharge from Twentymile Creek was only 4,000 acre-feet. Considering the two streams together, the maximum discharge of record is 77,800 acre-feet during March, 1910, the discharge being 49,600 acre-feet from Deep Creek and 28,200 acre-feet from Twentymile Creek.

Under the proposed project that portion of the Deep Creek discharge coming from Big Valley can be entirely held in the Big Valley Reservoir. In order to determine what portion of the Deep Creek discharge may be expected to be held back in Big Valley Reservoir, a comparison has been made of the discharge of Deep Creek at Big Valley and at Adel during the months of record when

the discharge approached flood conditions. Unfortunately the records of discharge were not kept at Big Valley during the spring of 1910, when the largest early flood conditions occurred from Deep Creek. During May, 1912, when the discharge from Deep Creek at Adel was 55,000 acre-feet, that of Big Valley was 21,200 acre-feet, or 38½ per cent. During the months of March, April, and May, 1914, the discharge of Deep Creek at Big Valley was 30, 52, and 74 per cent, respectively, of its discharge at Adel, indicating that the largest run-off from Big Valley may be expected later than that from the lower area tributary to Deep Creek. It appears from these studies that during the years of extreme run-off in the early part of the season, probably not more than 30 per cent of the run-off at Adel would come from Big Valley.

With the development proposed by the Modoc County Irrigation Company in Cowhead Lake and diversion of the upper branches of Twentymile Creek into it for the use in Surprise Valley, the flood run-off from Twentymile Creek would be materially reduced in a year of extreme run-off, largely because 36 square miles of the drainage area of Twentymile Creek is directly tributary to Cowhead Lake. The total effective diversion capacity of the canals diverting from Twelvemile, Keno, and Rock Creeks is taken at 200 second-feet in the tabulation to follow, and consequently the diversion during the month of 31 days would be about 12,000 acre-feet. The combined capacity of these canals will probably be in excess of 200 second-feet, but during a month would probably not divert more than the amount estimated.

Following is a tabulation of probable extreme monthly discharge to South Warner Valley in an extreme year such as described under "Necessity of flood control for the reclamation of marshlands," as modified by Big Valley storage and Cowhead Lake storage under the proposed project:

Probable extreme monthly discharge to South Warner Valley under proposed project.

		Acre-feet.	Acre-feet.
Deep Creek:			
50 per cent in excess of March, 1910		74,400	
Held in Big Valley Reservoir, 30 per cent		22,400	
Probable discharge from Deep Creek			52,000
Twentymile Creek:			
50 per cent in excess of March, 1910		42,300	
Held in Cowhead Lake Reservoir—			
Direct inflow, 40 per cent of above	16,900		
Diverted by canals	12,000		
		28,900	
Probable discharge from Twentymile Creek			13,400
Total probable monthly discharge South Warner Valley			65,400

The extreme condition outlined above would undoubtedly occur before the irrigating season, and this volume of water would have to be wasted in Coleman Valley or passed to Hart Lake, requiring a capacity of about 1,100 second-feet. The proposed plans provide for a waste canal of 350 second-feet capacity diverting to Coleman Valley from the East Canal, the canal in turn diverting from Deep Creek. The drainage canal from Crump Lake to Hart Lake would therefore be required to pass 750 second-feet during the entire month. Since the above estimate is based on an entire month, any extreme flood condition existing for a few days or weeks in excess of the regulating capacity of Crump Lake would require a still greater capacity in the drainage canal below that lake. For this reason the capacity for the drainage canal as planned has been taken at 1,000 second-feet from Crump Lake to Hart Lake.

Crump Lake, whose area is 1,250 acres, will act as a regulating reservoir for storing the extreme floods of a few days' duration, and thus allow of a smaller capacity in the drainage canal from this lake to Hart Lake. For example, if a temporary flood of 2,000 second-feet were to enter Crump Lake while 1,000 second-feet was being drawn from it, the lake would be filled at the rate of 2,000 acre-feet per day and its elevation would be raised 4 feet in 2½ days.

The capacity of the main drainage canal from Crump Lake south to the junction with the Deep Creek branch, a distance of 4.55 miles, will need to be sufficient to take care of maximum discharges of both Deep Creek and Twentymile Creek, as modified by storage at Big Valley and Cowhead Lake. The Deep Creek branch, and consequently the main channel below this branch, can also be reduced in capacity to the extent of the 350 second-feet which it is planned to waste in Coleman Valley. This amount will be diverted from Deep Creek at the upper end of the drainage canal, and passing along the East Canal will be taken from the latter to Coleman Valley by the waste canal.

Following is a tabulation of the high months of discharge from Deep Creek and Twentymile Creek, taken from Bulletin No. 4, State engineer's office, Water Resources of the State of Oregon. The maximum, however, represents a mean for one day and is not an absolute maximum.

High monthly discharges of Deep Creek near Adel, Oreg.

Month.	Discharge in second-feet.			Total run-off in acre-feet.
	Maximum.	Minimum.	Mean.	
1909–10.				
November	1,800	13	355	21,100
January	2,500	44	240	14,800
March	2,400	438	807	49,600
April	540	295	428	25,500
May	410	122	247	15,200
1910–11.				
March	1,260	24	298	18,300
April	1,260	122	456	27,100
May	810	244	445	27,400
June	880	110	426	25,300
1911–12.				
March	202	24	76.4	4,700
April	483	104	268	15,900
May	1,260	377	894	55,000
June	1,020	236	590	35,100
1912–13.				
March	1,340	26	116	7,130
April	1,260	172	563	33,500
May	730	319	583	35,800
June	552	69	255	15,200
1913–14.				
March	820	44	493	30,000
April	1,180	191	544	32,400
May	465	233	372	22,900
June	272	78	159	9,460

High monthly discharges of Twentymile Creek near Warner Lake post office.

Month.	Discharge in second-feet.			Total run-off in acre-feet.
	Maximum.	Minimum.	Mean.	
1910.				
March	2,610	115	458	28,200
April	148	98	118	7,020
May	112	37	66.2	4,070
June	36	7.5	18.6	1,110
1910–11.				
March	809	7.2	225	13,800
April	809	70	262	15,600
May	148	62	84.8	5,210
June	181	36	124	7,380
1911–12.				
March	232	5.7	23.9	1,470
April	46	12	25.4	1,510
May	127	30	65.2	4,010
June	143	30	78.6	4,680
1912–13.				
March	620	5.6	72.4	4,450
April	406	30	73.8	4,390
May	113	24	65.4	4,020
June	120	19	43.5	2,590
1913–14.				
March	740	42	339	20,800
April	580	48	121	7,200
May	146	55	109	6,700
June	96	20.2	46.8	2,780

In Water-Supply Paper 290 of the United States Geological Survey, Surface Water Supply of the United States, 1910, all the avail-

able data relating to stream measurements in Warner Valley for that year are given on pages 201 to 214. While the daily discharge for March 1 is given as 2,020 second-feet, a measurement made at 6.30 p. m. indicated a discharge of 3,340 second-feet. Similarly, on March 2 the daily discharge is given as 2,400 second-feet, but measured at 6 p. m. 4,950 second-feet.

It appears from the preceding tabulation that the ordinary yearly maximum discharge from Deep Creek is from 1,200 to 1,300 second-feet, but that in a year like 1910 it may reach 2,500 second-feet, with a flood for a few hours' duration of as much as 5,000 second-feet. A study of the maximum discharges of Deep Creek at Big Valley and at Adel during high-water stages makes it seem reasonable that storage as proposed at Big Valley will result in cutting down these maximum floods at least one-fourth.

Assuming flood conditions similar to those of early March, 1910, under the proposed project with storage at Big Valley, the possible discharge from Deep Creek on March 2 would have been 1,800 second-feet at Adel. Diverting 350 second-feet through the East Canal and waste canal to Coleman Valley, the resulting discharge through the drainage canal from Deep Creek would have been 1,450 second-feet, and on March 1, when Twentymile Creek was in flood stage, the discharge through the Deep Creek branch would have been about 1,050 second-feet.

With storage provided at Cowhead Lake the discharge of 2,610 second-feet from Twentymile Creek would probably have been reduced at least one-third, or 870 second-feet, by reason of direct inflow to the reservoir, and possibly 300 second-feet through the diversion canals from Twelvemile, Keno, and Rock Creeks, leaving a probable maximum discharge of 1,440 second-feet from Twentymile Creek. On March 2, during the flood stage of Deep Creek, Twentymile Creek discharged 2,020 second-feet, and under the proposed development this probably would have been reduced to 1,050 second-feet. Combining the discharges of these dates, the drainage channel from the Deep Creek branch to Crump Lake would have needed a capacity sufficient to pass 2,490 second-feet on March 1 and 2,500 second-feet on March 2.

This canal is planned to have a capacity of 1,900 second-feet with a depth of 10 feet below the ground surface. With water surface 2 feet above the ground surface, the capacity would be 2,500 second-feet and probably carry the flood of March 1 and 2, 1910. The spoil banks would probably be as high as the depth of cut, and if gates were provided for the lateral drainage canals this flood could have been confined entirely to the main drainage canal. Any discharges in excess of this 2,500 second-feet would probably be of only a few hours' duration, and if partly lost to the channel would not amount

to much in volume of water and would cause little damage at such time, although records indicate such floods may occur.

It has been the purpose in the figures of probable cost that follow to design these drainage channels south of Crump Lake of such capacity that they will take care of the maximum daily discharges in ordinary years, with the water surface not higher than the level of the ground through which the channels are constructed.

The drainage canal from Hart Lake and Flagstaff Lake will require a capacity slightly in excess of that between Crump Lake and Hart Lake, due to the possible flood discharge of Honey Creek, which enters Hart Lake from the west. Hart Lake has a storage capacity of 26,000 acre-feet in the 5 feet between its normal elevation and the lower elevation at which it is proposed to hold its surface during the early spring months. The maximum monthly discharge of Honey Creek during the period of record was 16,500 acre-feet in March, 1911, which was nearly approached in March, 1910, when the discharge was 16,400 acre-feet. If we assume that Crump and Hart Lakes were full as desired, as they undoubtedly would have been had the proposed project been in operation during 1909–10, then it would have been desirable to pass on to Flagstaff Lake in that month a large portion of the 16,400 acre-feet. This would have required an estimated additional capacity of 267 second-feet above the 1,000 second-feet required to pass on the amount received in Hart Lake from South Warner Valley, or a total capacity of 1,267 second-feet. Any excessive discharge which may be expected from Honey Creek, lasting but a few days, would be taken care of by the regulating action of Hart Lake as a reservoir.

The channels to be excavated between the lakes below Flagstaff Lake and as far north as Bluejoint Lake would not require very large cross-sectional areas, as a few inches difference in elevation between the successive sump lakes connected by short channels will induce high velocities in the connecting channels. The controlling feature in their design will probably be the narrowest channel at about 6 feet depth that will permit passing of the dredge to be used in the excavation, or say an average cross section of 6 by 25 feet, involving the excavation of about 30,000 cubic yards per mile.

The normal elevation of Crump Lake, which is about the elevation of the lowest surrounding tule lands, is about 1 foot higher than the normal elevation of Hart Lake. Under the proposed plans of using these lakes for storage for the lands to be served by pumping from Hart Lake, Crump Lake would ordinarily be kept about 5 feet below normal elevation and Hart Lake about 4 feet below normal elevation just previous to the opening of the irrigating season. A rise of 2 feet in Crump Lake would give a fall of 2 feet in the connecting channel 8 miles long, which will be constructed on a slope of 0.264 feet per

mile, and with a depth of 9 feet of water under the conditions just mentioned. The depth of cut required for this channel will vary from about 10 to 12 feet. A depth of at least 10 feet will be required throughout the main drainage channel to afford a required depth of drainage for the drainage laterals serving the adjacent lands. At the beginning of the irrigating season practically all water entering South Warner Valley will be diverted to the irrigating canals, and the pumping plant pumping from Hart Lake will immediately begin to lower Hart and Crump Lakes and their connecting channel, thus affording the required drainage for the surrounding lands. If the water level is not lowered rapidly enough to provide this drainage, the controlling gates at the north end of Hart Lake may be opened and the water level controlled as desired.

There is a fall of 8 feet from the normal elevation of Hart Lake to that of Flagstaff Lake. It is proposed to keep Flagstaff Lake at least 2 feet below its present normal or overflow elevation, which will leave a fall of 5 feet between its elevation and that of Hart Lake during ordinary operation and permit of a fall of about a half foot per mile in the connecting drainage channel. The canal as planned, with controlling gates at north end of Hart Lake, will permit the regulation of the surface of Hart Lake from 2 feet above normal to about 10 feet below normal elevation. This drainage canal will follow the present overflow channel, which is from 2 to 4 feet below the surrounding land between lakes, and will be excavated through the shallow Anderson and Mugwump Lakes. The average cut required is about 5 feet. This channel will serve as the main drainage canal for the surrounding marshlands.

From Crump Lake south the lowest portion of the marshlands rises about 0.8 foot per mile. The drainage canals as planned will have about 10 feet depth below the ground surface.

For more details of length, width, depth, and capacity of the main drainage channels see "Construction designs and estimates of cost."

In addition to the main drainage channels described lateral drains from the main channels will be required, which in turn will be the collecting channels from farm drains. These should probably be not less than a mile apart and reach about to the edge of the meadowland. As planned, these will vary in depth from 10 feet at the main drainage channels to 6 feet at their beginning, with 1 to 1 side slopes. The total length of required lateral drains is estimated to be about 70 miles.

LAND AND WATER WITHDRAWALS.

Lands.—In compliance with the terms of the agreement between the United States and the State providing for these investigations, public lands within the limits shown on Plate No. 1, Warner Valley project, have been withdrawn from entry for Big Valley and Cole-

man Valley Reservoir sites. No other public lands are withdrawn from entry for this project.

Water.—In further compliance with this agreement the waters required for this project have been withdrawn by the State engineer from appropriation as follows:

Any and all unappropriated water of Warner Lakes, composed of a string of lakes known as Crump, Hart, Anderson, Mugwump, Flagstaff, Bluejoint, and other lakes, also all unappropriated water of Twentymile, Deep, Warner, Snyder, and Rabbit Creeks, including the tributaries thereof, and all other streams tributary to the lakes above mentioned in Warner Valley in Lake and Harney Counties, Oreg., was withdrawn by the State engineer on August 23, 1915, under applications Nos. 4477 and 4478.

Also 100,000 acre-feet of water of Deep Creek and its tributaries to be stored in Big Valley Reservoir were withdrawn by the State engineer on February 28, 1916, under application No. 4774.

POWER POSSIBILITIES.

Big Valley, on upper Deep Creek, and the Mud-Camas Reservoir site on Camas Creek, are about 1,000 feet above the bottom of Warner Valley near Adel. The greater part of this drop in elevation occurs in two distinct drops of about 400 feet each, which furnish excellent opportunities for power development on Deep Creek.

The upper Deep Creek power site may be divided into two parts for convenience in description, but not necessarily so for power development. There is a 200-foot drop on Deep Creek from its junction with Camas Creek to the junction with Drake Creek, a distance of about 2 miles. Above the junction with Camas Creek, Deep Creek has a fall of 250 feet in about 1½ miles, while Camas Creek above this junction has a fall of 250 feet in about 2 miles. For utilization of the upper fall of 250 feet two power canals would be required, one along each stream canyon. A power plant at the junction of the streams could utilize the available drop at this point, and a power canal from the tailrace of this plant be conducted down Deep Creek Canyon to the junction with Drake Creek, where the second plant would be located to utilize the second drop of 200 feet. As an alternative plan, the upper power canals would be joined by conducting the united flow down Deep Creek Canyon to the lower site and utilizing the entire 450 feet fall at one plant.

The mean yearly available supply from Big Valley storage under the proposed project has been estimated to be 43,000 acre-feet. The mean yearly flow from Deep Creek at Adel is estimated to be 115,500 acre-feet, while that from Big Valley is estimated to be 52,000 acre-feet, leaving 63,500 acre-feet as the flow from Deep Creek below Big Valley, Camas Creek, Drake Creek, and other lower tribu-

tary areas. Assuming that Drake Creek and other areas drained into Deep Creek below the junction of Deep and Camas Creeks furnish as much as 13,500 acre-feet, there remains 50,000 acre-feet as the probable flow from Camas Creek and Deep Creek between the junction and Big Valley. The yearly discharge available for power at the upper site would thus be 93,000 acre-feet, of which it is estimated 60,000 acre-feet would be available during the irrigating season of 100 days, or the equivalent of a continuous flow of 300 second-feet. With a fall of 450 feet there could be developed 15,300 theoretical continuous horsepower, or 11,000 actual continuous horsepower for 100 days, estimating 72 per cent efficiency in penstocks and power plant. In addition, there would be 33,000 acre-feet available during the remainder of the year, the equivalent of 850,000 theoretical horsepower days, or 610,000 actual horsepower days.

The total power possible to develop at this site is therefore 1,710,000 actual horsepower days, equivalent to a continuous all-the-year power of 4,700 horsepower. There could probably be maintained a minimum flow at this power plant of 20 second-feet in conjunction with Big Valley storage, without materially affecting the irrigation use, which would give a continuous estimated power for commercial use of 735 horsepower at this plant.

By developing the Mud-Camas Reservoir site, as outlined under "Reservoir sites," the 50,000 acre-feet not coming from Big Valley could be distributed throughout the remaining 265 days of the year to furnish continuous power for commercial use, if so desired. Records of discharge for 1912–1913, which year is slightly below the normal, indicate a run-off from the Mud-Camas Reservoir site of 27,700 acre-feet. If we assume 30,000 acre-feet as the mean run-off and provide storage for this amount, 965 acres would be flooded at maximum stage, and the probable evaporation would be about 2 feet on 600 acres, or 1,200 acre-feet. Seepage lost to the stream below would be probably 10 per cent, or 3,000 acre-feet. The net available amount from Mud-Camas Reservoir would thus be 25,800 acre-feet. This amount distributed through the 265 days of the nonirrigating season would give a continuous flow of 49 second-feet, which, with a minimum flow of, say, 3 second-feet from the lower streams, such as Crane and Sage Hen Creeks, would furnish a continuous minimum flow of 52 second-feet and furnish through the 450-foot drop 1,920 continuous actual horsepower.

The lower Deep Creek power site is furnished by a fall of about 400 feet from the head of the Deep Creek Falls, about 3 miles west of Adel, to the foot of a small fall in Deep Creek about a mile west of Adel and just below the diversion of the "M.C."-Given Ditch from Deep Creek. Two miles of power canal would be required. Estimating that the three ditches diverting above the point at which

water would be returned to Deep Creek might require 3,500 acre-feet, and that Big Valley storage losses would reduce the available supply by 7,000 acre-feet, there would remain 105,000 acre-feet as the mean yearly amount available for power development at this site. With a fall of 400 feet there would be available 2,400,000 theoretical horsepower days, or, with 72 per cent efficiency in power plant, 1,730,000 actual horsepower days.

There could probably be maintained for this power development a minimum flow of 25 second-feet in conjunction with Big Valley storage without materially affecting irrigation use, and thus furnish for commercial use 820 continuous horsepower. With the Mud-Camas storage development as outlined, the minimum flow could be maintained at about 57 second-feet, which would furnish at this power site 1,860 continuous horsepower.

The total power possibilities on Deep Creek at both sites in conjunction with Big Valley storage is thus 3,440,000 horsepower days, with a possible minimum power of 1,550 horsepower for the entire year and 28,700 horsepower for a 100-day period. With additional storage at the Mud-Camas reservoir site to regulate minimum flow, the power available for commercial use on an all-the-year basis at both sites is 3,780 horsepower, with a balance of 21,200 horsepower available for a 100-day period.

The probable cost of this power development for both sites, considering the cost of the Mud-Camas storage development as chargeable to the continuous power for commercial use and the Big Valley storage cost as entirely chargeable to irrigation development, is as follows:

Probable cost of commercial power.

Mud-Camas storage, 30,000 acre-feet, at $6	$180, 000
Power canals, one-half of 7½ miles, at $10,000 per mile	37, 500
Penstocks	20, 000
Power house and equipment, 3,780 horsepower, at $40	151, 200
	388, 700
Engineering, administration, and contingencies, 25 per cent	97, 300
Total, 3,780 horsepower	486, 000
Probable cost per horsepower generator output	125

Probable cost of power for pumping.

Power canals, one-half of 7½ miles, at $10,000	$37, 500
Penstocks	120, 000
Power house and equipment, 20,000 horsepower, at $40	800, 000
	957, 500
Engineering, administration, and contingencies, 25 per cent	239, 500
Probable total cost, 20,000 horsepower	1, 197, 000
Probable cost per horsepower generator output	60

CONSTRUCTION DESIGNS AND PROBABLE COSTS.

BIG VALLEY STORAGE.

It has been shown under "Storage requirements" that the capacity required for Big Valley storage is about 44,000 acre-feet. The records of discharge under "Water supply" indicate that about 50,000 acre-feet is the mean discharge from Big Valley. A dam 30 feet high and less than 500 feet long at the crest line would store the required 44,000 acre-feet. On account of the relatively cheap storage at Big Valley and the necessity for holding back as much water as possible in any year or period of years of extreme run-off, it is planned to develop the storage here to about 100,000 acre-feet. For this storage capacity a dam 57 feet high and about 500 feet long at the crest line will be sufficient to raise the water 50 feet, and the cost of the reservoir lands for this development will be but little greater than for the development for 44,000 acre-feet. The dam as planned is of earth fill type, with 3 to 1 slope on the reservoir side, 2 to 1 slope on the downstream face, and a 20-foot crest width.

The spillway, located at the south end of the dam, will have a 110-foot crest length, and with water at 4 feet and at 6 feet on the spillway crest, will discharge 3,500 and 6,800 second-feet, respectively. The drainage area at Big Valley is about 71 square miles, and the spillway as planned will therefore take care of a discharge of 100 second-feet per square mile into the reservoir, with a depth of about 6.1 feet on the spillway crest or 0.9 foot below the top of the dam.

The outlet works will require a relatively large discharge capacity, due to the fact that the May and June uses will come largely from the direct flow of Camas, Twentymile, and Honey Creeks, and from earlier flow of these streams stored in Crump and Hart Lakes. The July and August flow from these streams is very small in ordinary years, and the July use for all the lands in South Warner Valley will need to come almost entirely from Big Valley storage. The early flow stored in Crump and Hart Lakes will be nearly depleted by the end of June, so that the July supply for the lands to be served by pumping from Hart Lake will have to come largely from Big Valley storage also. The total supply required in July from storage will likely range from 21,000 acre-feet in ordinary years to about 30,000 acre-feet in years when one or more of the streams may have an unusually early run-off. For this latter supply the outlet works will have to be of sufficient capacity to discharge 500 second-feet.

The outlet as planned provides for a conduit under the dam at the creek elevation just north of the channel, this conduit to have an opening of 30 square feet and to be constructed of reinforced concrete, with 20 collars to prevent seepage along the conduit. The length of conduit planned is 280 feet. Control of discharge through

this conduit will be by two pairs of gates, 3 feet by 5 feet, in the bottom of a concrete tower located at the toe of the dam. Following is the probable detailed cost of Big Valley dam and reservoir lands:

Probable cost of Big Valley Reservoir.

Embankment:		
Stripping, 2,400 cubic yards, at $0.50	$1,200	
Cut-off excavation, 2,000 cubic yards, at $1	2,000	
Earth fill from borrow, 66,000 cubic yards, at $0.60	39,600	
Rock fill from spillway, 4,500 cubic yards, at $0.25	1,125	
Riprap from spillway, 3,500 cubic yards, at $0.75	2,625	
		$46,550
Spillway:		
Rock excavation, 6,000 cubic yards, at $1.50	9,000	
Plain concrete retaining walls, 400 cubic yards, at $18	7,200	
Reinforced concrete spillway weir, 100 cubic yards, at $20	2,000	
Steel reinforcement, 6,000 pounds, at $0.07	420	
		18,620
Outlet tower and conduit:		
Concrete, tower, and conduit, 640 cubic yards, at $20	12,800	
Steel reinforcement, 27,000 pounds, at $0.07	1,890	
Excavation and back fill	1,000	
Gates in place, four, 3 by 5 feet, at $750	3,000	
Bridge	640	
		19,330
Miscellaneous:		
Building for gatekeeper	1,500	
Building and repairing road from Camas Prairie	4,000	
		5,500
		90,000
Engineering, administration, and contingencies, 25 per cent		22,500
		112,500
Reservoir lands:		
3,000 acres, at average of $20	60,000	
1,000 acres, at average of $10	10,000	
Purchasing, legal, and administration	5,000	
		75,000
Total		187,500

COLEMAN VALLEY STORAGE.

It has been shown under "Necessity of flood control for reclamation of marshlands" that it will be necessary to dispose of as much water as possible in years of high run-off and to keep this water away from the marshlands. Coleman Valley offers an excellent site for this purpose. A branch canal 3 miles in length from the East Canal to Coleman Valley outlet will permit of running 350 second-feet into Coleman Valley before the irrigating season begins. A 10-foot drainage channel through the outlet would permit of running 60,000 acre-feet into Coleman Valley and drawing back 30,000 acre-feet during

BIG VALLEY DAM SITE, LOOKING DOWNSTREAM.

the irrigating season. About 10,000 acre-feet more in the reservoir above the elevation of the bottom of the outlet could not be withdrawn during the irrigating season on account of the nearly level grade of the outlet channel for about 5 miles. Such operation of this storage will permit of keeping Crump and Hart Lakes in ordinary years well below the elevation at which adjoining marshlands might be injured by water backing up in the drainage channels. Under this plan for storage in Coleman Valley no dam will be required, but controlling gates at the outlet to Coleman Valley and below the place where the feed canal discharges into the drainage canal will be necessary. In the following figures of cost this drainage channel and the controlling gates are included in order to make a comparison of storage costs in Coleman Valley and in the Mud-Camas Reservoir site, already given under "Reservoir sites."

Probable cost, Coleman Valley storage.

Feed canal, 17,000 feet, branch of East Canal, 161,500 cubic yards, at $0.20	$32,300
Drainage outlet, 475,000 cubic yards, at $0.12	57,000
Controlling gates	2,000
	91,300
Engineering, administration, and contingencies, 25 per cent	22,700
Total	114,000

Probable cost per acre-foot available, 30,000 acre-feet, $3.80.

It thus appears that while Coleman Valley storage is comparatively cheap for about 30,000 acre-feet, yet the yearly loss, if it were operated as a storage reservoir, would be great from evaporation on its surface of about 5,000 acres, and the 5 miles of level outlet would make it difficult to withdraw the stored water as rapidly as might be desired unless the outlet channel were made with a much larger cross section than required for filling the reservoir. Under the project proposed, storage will not be required in Coleman Valley for ordinary years, and for years of low run-off such storage would be wasteful of water. In years of extreme run-off, however, it will be necessary to waste as much water as possible in Coleman Valley. The two playa lakes in the entrance to Coleman Valley can be utilized by a waste canal from the East Canal to Coleman Valley, no excavation being required across the beds of these dry lakes. The probable cost of this waste canal, involving 304,000 cubic yards of excavation (see "Drainage canals") is about $78,000, or a saving of about $36,000 over the deep dredged channel for the storage scheme.

It is possible that Coleman Valley would be required for storage should a project be undertaken involving a greater acreage than in the proposed project and in consequence more storage, or should the

proposed project be extended later. In any event the use of Coleman Valley as a waste reservoir, with waste canal, would not involve work which would result in loss should it be found desirable later to deepen the outlet and use Coleman Valley as a storage reservoir. Coleman Valley will therefore, in the proposed project, be considered as a waste reservoir for disposing of water in years of extreme run-off, and figures of probable cost will include only the waste canal.

For length, slope, and dimensions of this waste canal as planned, see tabulation under "Drainage canals." Quantities of excavation are also given. Following is the probable cost of Coleman Valley storage under the proposed project:

Probable cost of Coleman Valley storage for waste only.

Waste canal, 9.5 miles:	
Earth excavation, 304,000 cubic yards, at $0.20	$60,800
Highway bridge, one, at $100	100
Telephone line, 8 miles, at $250	2,000
	62,900
Engineering, administration, and contingencies, 25 per cent	15,100
Total estimated cost	78,000

DRAINAGE CANALS.

The proposed drainage system has been described at length under "Drainage." For location of these drainage canals see map showing proposed project, Plate No. 1.

The figures of probable cost of these drainage channels are based on operating dredges by electric power generated at the plant to be constructed at the Deep Creek Falls, this power to be ultimately used for pumping from Hart Lake for irrigation. The first cost of this power development is therefore not included in the cost for drainage, but the operating cost is included in the unit price per cubic yard. The dredges used will be of the revolving steam-shovel or drag-line excavation type, mounted on a barge about 22 or 24 feet in width. The dipper or bucket used should be of about 1½ to 2 cubic yards capacity, and capable of dumping at least 60 feet on either side of the center of the channel being excavated. These shovels or excavators will be so designed that they can be taken from the barges and used later in excavating the main open drainage laterals. The price used for the cost of the laterals is based on the performance of such excavators in similar work in other localities.

It is expected that it will take four such excavators at least two years to excavate 2,284,000 cubic yards in the drainage channels, as tabulated below. The average monthly yardage excavated by each

machine on the basis of two years would be nearly 24,000 cubic yards. Records as high as 30,000 cubic yards per month by such dredges have been made, but this could hardly be expected to be maintained for such a long period. No depreciation has been considered in arriving at the probable cost of this class of excavation, but the entire first cost of the dredges is charged to the work.

Following is a tabulation showing length, grade, width, capacity, and yards of excavation in different sections of the main drainage channels:

Drainage canals.	Length.	Fall per mile.	Width in feet.		Capacity.	
			Top.	Bottom.	Depth.	Second-feet.
	Miles.	*Feet.*			*Feet.*	
Connecting Sump Lakes, Bluejoint to Upper Flagstaff	4.0	0.528	30	25	10	720
Flagstaff to Hart Lake	9.3	.528	[1] 70	40	10	1,280
Hart to Crump Lake	4.0	.264	42	36	12	1,000
	4.0	.264	42	36	12	1,000
Crump Lake—south:						
Mile 0 to 4.55	4.55	.792	60	55	12	2,500
Mile 4.55 to 9.50	4.95	.792	36	32	10	1,000
Mile 9.50 to 11.50	2.00	.792	36	32	10	1,000
Deep Creek Branch	1.15	.792	40	35	12	1,650
Total	33.95					
Coleman Valley	3.22	.264	44	20	7.7	350
Waste canal	1.88	(2)	(2)	(2)		
	.95	.528	36	12	7.7	350
	1.53	(2)	(2)	(2)		
	1.92	.528	36	12	7.7	350
Total	9.50					

Drainage canals.	Depth of cut.	Excavation per mile.	Total excavation.
	Feet.	*Cu. yds.*	*Cu. yds.*
Connecting Sump Lakes, Bluejoint to Upper Flagstaff	6.0	30,000	120,000
Flagstaff to Hart Lake	5.0	41,000	381,000
Hart to Crump Lake	13.4	102,000	408,000
	12.0	90,000	360,000
Crump Lake—south:			
Mile 0 to 4.55	10.0	112,000	510,000
Mile 4.55 to 9.50	10.0	65,000	322,000
Mile 9.50 to 11.50	9.0	52,500	105,000
Deep Creek Branch	10.0	68,000	78,000
Total			2,284,000
Coleman Valley	8.0	50,000	161,500
Waste canal	9.0	45,000	42,500
	10.0	52,800	100,000
Total			304,000

[1] 15-foot berm to be left on each side of 5-foot cut.
[2] Level (Playa Lake).

It is hardly to be expected that the open lateral drains 1 mile apart will result in adequate drainage to all the lands. Some areas may not require more, but others will probably require additional drains from the main laterals. Tile drainage from these laterals would probably cost from $5 to $10 per acre in such areas. However, the need of

such can hardly be anticipated and the cost of this farm drainage will not be included in this estimate. Following is the probable cost of drainage as proposed:

Probable cost of drainage.

Dredges, 4, delivered and set up, at $25,000	$100,000
Transmission lines, branch, 30 miles, at $400	12,000
Portable transformer substations with operating cable, 4, 150 kilowatts, at $2,000	8,000
Main drainage canals, excavation, 2,284,000 cubic yards, at $0.08	183,000
Drainage laterals, 70 miles, at $2,500	175,000
	478,000
Engineering, administration, and contingencies, 25 per cent	119,500
Total construction cost	597,500
Cost per acre, 46,000 acres	13.00

STRUCTURES FOR DRAINAGE AND LAKE CONTROL.

No detailed statement has been made of structures required for drainage and lake control. The controlling gate for the drainage canal from Coleman Valley has already been referred to. Controlling gate at the north end of Crump Lake will be required to control the discharge into the drainage canal below, in order to operate Crump Lake as a reservoir. In the same manner, a controlling gate will be required at the outlet to Hart Lake. It has been shown under "Necessity of flood control for reclamation of marshland" that under the proposed plan more water can be used and disposed of each year than the mean discharge into the valley. It will therefore be seen that the lakes below Flagstaff Lake will be dry at the close of each season during a period of ordinary run-off into the valley. Now, let it be assumed that a heavy spring run-off enters the valley and that the excess water is allowed to pass into Flagstaff, Bluejoint, and intermediate lakes are filled to a depth of 5 or 6 feet. As soon as irrigation use commences to draw down Flagstaff Lake it will be desirable to relieve the marshlands around Mugwump Lake by pumping. In such case the controlling gate between Flagstaff Lake and the next lower lake will be necessary to prevent the water, which will in time doubtless become more alkaline, from flowing back into Flagstaff Lake. Following is the probable cost of structures for drainage and lake control:

Probable cost, structures for drainage control.

Controlling gates at Crump Lake outlet	$6,000
Controlling gates at Hart Lake outlet	6,000
Controlling gates at outlet from Flagstaff Lake	5,000
	17,000
Engineering, administration, and contingencies, 25 per cent	4,200
Total	21,200

GRAVITY DISTRIBUTION.

Canals.—The distribution in South Warner Valley as planned will be by three gravity canals and their distributing laterals. The location and capacities of these canals are described under "Proposed project." The canals have been designed for an average loss of 25 per cent between diversion and lands to be served. Following is their probable cost:

Probable cost of canals.

East Canal, 16.7 miles:	
Diversion and wasteway (Deep Creek)	$3,000
Excavation, 195,500 cubic yards earth, at $0.20	39,100
Flume crossing main drainage canal	2,220
Fencing, 32 miles, at $125	4,000
Culverts, 4, at $100	400
Highway bridges, 12, at $100	1,200
Telephone line, 16.7 miles, at $250	4,200
	54,120
Warner Canal, 15 miles:	
Diversion and wasteway	2,000
Excavation—	
130,000 cubic yards earth, at $0.20	26,000
6,640 cubic yards loose rock, at $0.50	3,320
Flume crossing Twentymile Creek	1,600
Right of way, 2 miles, at $600	1,200
Fencing, 30 miles, at $125	3,750
Culverts, 8, at $100	800
Highway bridges, 4, at $100	400
Telephone line, 15 miles, at $250	3,750
	42,820
South Canal, 7.2 miles:	
Diversion and wasteway	2,000
Excavation, 69,780 cubic yards, at $0.20	13,960
Flume crossing drainage canal	4,250
Fencing, 14 miles, at $125	1,750
Culverts, 3, at $100	300
Highway bridges, 3, at $100	300
Telephone line, 7 miles, at $250	1,750
	24,310

Distributing laterals and structures.—The distributing laterals in South Warner Valley will necessarily be of large cross section on account of the small slopes in the valley bottom. There will be required no rock work and no special structures, such as pipe-line drops. The duty of water assumed for this project, 1.5 acre-feet per acre, will require somewhat larger distributing laterals than for the Silver Lake project, for example, in which the duty of water assumed is 1 acre-foot per acre on the land. In connection with that project the distributing laterals and structures were considered

for units varying from 1,000 to 7,500 acres, and a table of graded costs worked up for that project. See Silver Lake Project Report, page 138. For this report a computation has been made of the increased yardage and excavation necessary to serve the 7,500-acre unit, which makes the probable costs of laterals and structures for distributing to such a unit $4.65, in the place of $4.21 for the Silver Lake project. Since the figures have been made for the main canals to serve the units of 17,500, 8,000, and 7,500 acres under each, these units have been divided into subunits, which would naturally be served by laterals from the main canals, and in this manner a probable average acre cost for distributing laterals and structures has been determined at $3.80 per acre. It should be noted, however, that this provides only for wooden structures, such as turnouts, measuring boxes, and weirs.

Probable cost of gravity distribution.

East Canal	$54,120
Warner Canal	42,820
South Canal	24,310
Distributing laterals and structures, 33,000 acres, at $3.80	125,400
	246,650
Engineering, administration, and contingencies, 25 per cent	61,350
Total	308,000
Cost per acre, 33,000 acres	9.35

PUMPING DISTRIBUTION.

Under the proposed project, distribution in North Warner Valley will be by pumping from Hart Lake to serve 21,000 acres, and from Flagstaff Lake to serve about 6,000 acres. The location of these pumping plants is shown on Plate No. 1. Detailed figures of probable cost have not been made of the main canal for serving these units. with the exception of that from the Hart Lake pumping plant to the Plush pumping plant, a distance of about 3 miles. Following is a tabulation of the maximum power required for pumping to these lands:

Power requirements for pumping in North Warner Valley.

Plant.	1	2	3	4	5	6	7
Hart Lake	13,000	222.0	15	378	63.0	600	670
Plush	6,000	70.0	42	340	63.0	540	600
North Hart	2,000	23.5	36	96	[1] 60.0	160	180
Flagstaff	6,000	70.0	40	320	63.0	510	560
Total, 4 plants	27,000	385.5	....	1,134	....	1,810	2,010

[1] Pump unit efficiency reduced to 60 per cent on account of small pumps used.

1. Acres to serve.
2. Second-feet pumped (maximum duty).
3. Pumping head in feet, including friction head for maximum duty.
4. Theoretical horsepower required.
5. Pump unit efficiency: Pump, 70 per cent; motor, 90 per cent.
6. Horsepower required at motors.
7. Horsepower required at lower plant; 10 per cent loss in transmission.

Power and transmission—It is proposed to construct a power plant just below the Deep Creek Falls for the development of 2,000 electrical horsepower, this to be used during the construction period for operating electrical dredges, and on completion of the project to operate the various pumping plants. Deep Creek Falls is about 3 miles west of Adel. Here Deep Creek is in a gorge about 100 feet wide and falls abruptly over a hard lava ledge through a vertical drop of about 30 feet. A steep drop continues below the falls, so that a 50-foot fall can be easily utilized in a distance of about 400 feet. The power development here planned is a low concrete dam just above the falls to raise the water about 6 feet for diversion into a power canal of 500 second-feet capacity, which will follow the south side of the steep canyon for about 400 feet, where there is a favorable location for a power house. The penstocks required will not be longer than 100 feet each.

The transmission line will follow down Deep Creek Canyon nearly to Adel, then along the main Adel-Plush road to Plush, and continue northward to the Flagstaff pumping plant. A branch line about 4 miles long will be required to serve the Hart Lake and North Hart Lake pumping plants.

Following is the probable cost of power development and transmission lines:

Probable construction cost of power and transmission.

Power:		
Diversion dam and gates	$12,000	
Power canal, 400 feet, and forebay, concrete lined	7,600	
Penstocks	5,000	
Power house, discharge tubes, and excavation	5,400	
Equipment, 2,000 electric horsepower, at $40	80,000	
		$110,000
Transmission:		
Main transmission line, 34 miles, at $2,000	68,000	
Branch transmission line, 4 miles, at $800	3,200	
		71,200
		181,200
Enginering, administration, and contingencies, 25 per cent		45,300
Total		226,500

Pumping plants.—The Hart Lake pumping plant as proposed will be located on the present bank of Hart Lake about 1 mile north and 2 miles east of Plush. The pumping plant is designed to pump from the lake with the surface of the water fluctuating from 2 feet to 10 feet below the present normal elevation of the lake. This pumping plant will be required to pump 220 second-feet to a lift varying with the lake level from 7 to 15 feet to serve altogether 19,000 acres, 10,000 acres of which lie to the north of Hart Lake and 3,000 acres to the south of the plant in a strip from one-half to one and one-half

miles wide west to Hart Lake. The maximum pumping head, including friction head, will probably not exceed 15 feet during July, the month of maximum duty. The canal serving this 3,000 acres, running southwesterly from the pumping plant, will reach the foot of the steep slope about a mile south of Plush. The Plush pumping plant will be located here to pump from this canal 40 feet higher to a canal which will serve 6,000 acres lying above and to the west of the lands just described.

The proposed plans for the Hart Lake pumping plant provide for about 100 feet of steel flume to carry the discharge from the pipes to the discharge canals.

The Plush pumping plant will be required to lift 70 second-feet against a pumping head of 42 feet. Delivery from this pumping plant to the higher canal will be by 1,000 feet of 48-inch wood-stave pipe.

The North Hart pumping plant will be located at the outlet of Hart Lake, on the east shore of the lake, to lift about 23½ second-feet to an elevation 30 feet above that at which it is planned to store water in Hart Lake, against a pumping head varying from 30 to 40 feet. Delivery from the pumping plant to the canal will be through 600 feet of 30-inch wood-stave pipe to the distributing canal, which will run northward to irrigate a strip of land about a half mile wide as far north as Anderson Lake. The maximum pumping lift, including 2 feet for friction, will probably not exceed 36 feet during June, the month of maximum duty.

Flagstaff pumping plant will be located about a half mile west of Flagstaff Lake, to which a dredged channel will conduct the water from the pumping plant. The plant will be required to lift 70 second-feet to an elevation of 4,490 feet against a pumping head varying from 36 feet to 42 feet. The pumping head, including friction during maximum duty, is estimated to not exceed 40 feet. This pumping plant and delivery pipe as designed is an exact duplicate of the Plush pumping plant. Following are the probable costs of these pumping plants:

Probable cost of Hart Lake pumping plant.

Excavation, pump station and approach channel		$1,000
Pumping station:		
Foundations, 140 cubic yards concrete, at $10	$1,400	
Superstructures	1,200	
		2,600
Draft and discharge tubes, 120 feet 52-inch riveted steel tubes, 300 pounds per foot, at $0.06		2,160
Flume (plant to canal):		
Steel flume, 1,000 feet, at $5.90	$5,900	
Trestle, 30,000 feet b. m., at $20 erected	600	
		6,500

Transformers, 630 horsepower, at $5 erected		$3,150
Switchboards, 630 horsepower, at $3.50 erected		2,200
Machinery, three 30-inch centrifugal pumps and motors, at $4,000		12,000
Erection, freight, and haul, 254,000 pounds		4,510
		34,120
Engineering, administration, and contingencies, 25 per cent		8,530
Total		42,650

Probable cost of Plush pumping plant.

Pumping station:		
Excavation for foundations	$400	
Pump house	2,600	
		$3,000
Draft tubes, three 20-foot, 22-inch steel tubes, 62 pounds, at $0.06	225	
Discharge tubes, three 20-foot, 32-inch steel tubes, 80 pounds, at $0.06	288	
Discharge pipe line, 1,000 feet 48-inch wood-stave pipe, at $2.40	2,400	
		2,913
Machinery:		
Three 20-inch centrifugal pumps and motors, at $2,500	7,500	
Transformers, 500 horsepower, at $5	2,500	
Switchboards, 500 horsepower, at $3.50	1,750	
		11,750
Erection, freight, and haul, 94,700 pounds		1,740
		19,403
Engineering, administration, and contingencies, 25 per cent		4,847
Total		24,250

Probable cost of Flagstaff pumping plant.

Pumping station equipment, draft and discharge tubes (same as Plush plant)	$19,400
Channel dredged from Flagstaff Lake	8,600
	28,000
Engineering, administration, and contingencies, 25 per cent	7,000
Total	35,000

Probable cost North Hart pumping plant.

Pump house and excavation		$1,000
Machinery:		
Two 12-inch centrifugal pumps and motors, at $1,900	$3,800	
Transformers, 165 horsepower, at $5	825	
Switchboards, 165 horsepower, at $3.50	575	
		5,200

Draft tubes, two 50-foot, 14-inch steel tubes, 43 pounds (in place)	$330	
Discharge tubes, two 20-foot, 18-inch steel tubes, 52 pounds, at $0.06	125	
Discharge pipe line, 600 feet 30-inch wood-stave pipe, at $1.50	900	
		$1,355
Erection, freight, and haul, 48,580 pounds		965
		8,520
Engineering, administration, and contingencies, 25 per cent		2,130
Total		10,650

Summary, probable costs of pumping plants.

Hart Lake pumping plant, total construction cost	$42,650
Plush pumping plant, total construction cost	24,250
Flagstaff pumping plant, total construction cost	35,000
North Hart pumping plant, total construction cost	10,650
Total	112,550

Distributing canals, laterals, and structures.—Detailed figures of the probable cost of canals for distributing water from the various pumping plants have not been made, with the exception of the canal from Hart Lake pumping plant to the Plush pumping plant. Following is the probable cost of the distributing canals, laterals, and structures:

Probable cost, distributing canals, laterals, and structures for pumping units.

Canal, Hart pumping plant to Plush pumping plant:		
Excavation, earth, 30,260 cubic yards, at $0.20	$6,050	
Headgates near Hart pumping plant	200	
Flume crossing Honey Creek	1,000	
Fencing, 6 miles, at $125	750	
Culverts, 3 miles, at $100	300	
		$8,300
Distributing canals, laterals, and structures:		
10,000 acres, at $5.65	56,500	
3,000 acres, at $3.35	10,050	
6,000 acres, at $4.40	26,400	
2,000 acres, at $2.85	5,700	
6,000 acres, at $4.40	26,400	
		125,050
		133,350
Engineering, administration, and contingencies, 25 per cent		33,350
Total		166,700

Probable cost per acre, 27,000 acres, $6.15.

SUMMARY PROBABLE COST OF PROPOSED PROJECT.

The following is a tabulation of the probable cost of the different features required for the proposed project:

Total probable cost and cost per acre of proposed project.

Big Valley storage, total		$187,500
Coleman Valley waste canal		78,000
Drainage:		
Drainage canals and laterals, total		597,500
Drainage and lake control, total		21,200
Gravity distribution, total: Canals, distributing laterals, and structures		308,000
Pumping distribution, total:		
Power and transmission	$226,500	
Pumping plants	112,500	
Distributing canals, laterals, and structures	166,700	
		505,700
Miscellaneous:		
Telephone lines along drainage canals, 35 miles, at $250	8,750	
Telephone lines, Adel to Big Valley, 15 miles, at $250	3,750	
Roads for construction and maintenance	5,000	
Improving Deep Creek Channel from East Canal to Adel	5,000	
	22,500	
Engineering, administration, and contingencies, 25 per cent	5,500	
Total miscellaneous cost		28,000
Probable total construction cost, proposed project		1,725,900

Probable cost per acre, 60,000 acres, $28.77.

OPERATION AND MAINTENANCE.

The operation and maintenance of an irrigation system are so closely connected in actual performance of the work and in cost keeping that they are usually included under one head of operation and maintenance.

Gravity projects.—In the following tabulation of operation and maintenance for Orland, Truckee-Carson, and Klamath projects from the date of their earliest records of operation and maintenance cost keeping, the acre costs for land actually irrigated and for gross area actually being served are given:

Operation and maintenance cost per acre, United States Reclamation Service projects.

Year.	Orland, Cal.		Truckee-Carson, Nev.		Klamath, Oreg.	
	Per acre irrigable.	Per acre irrigated.	Per acre irrigable.	Per acre irrigated.	Per acre irrigable.	Per acre irrigated.
1909				$1.34	$0.53	$0.79
1910		$2.57		1.42	.58	.80
1911	$0.49	2.55		1.33	.69	.84
1912	.94	3.11	$0.89	1.24	.46	.59
1913	.93	2.02	.92	1.11	.78	1.13
1914	1.34	2.61	.81	1.06	1.05	1.47

In the Orland project the year 1913 showed a decrease from the year 1912. The year 1914 would undoubtedly have shown a further decrease but for the fact that exceptionally heavy storms caused much damage to canals and to the headgates at the main diversion from Stony Creek. The repairs to these damages of course properly belong to maintenance, and were therefore so charged.

In the Klamath project there is a small decrease in cost of operation and maintenance for the year 1912 from that of preceding years. For the year 1913, however, the acre cost for both irrigable and irrigated land increased, and for the year 1914 a still further increase in cost is noted. This increase in cost was due principally to the fact that the earlier wooden structures of the project began to be replaced about this time. There was also included in the year 1913 a drainage charge of about 40 cents per acre irrigable and about 61 cents per acre irrigated.

The Warner Valley project can probably be best compared to Klamath project or to Truckee-Carson project than to the Orland project. From the records of the last three years, when conditions must have become more normal, it appears that the operation and maintenance of a project such as the Warner Valley project should not exceed $1 per acre of irrigable area for the land served by gravity canals.

Attention is called to the fact that wooden structures, such as turnouts, gates, etc., on the Klamath project had to be replaced about the fifth or sixth year after construction. This should be anticipated for the Warner Valley project, for which the figures of probable costs given in this report are based on all minor structures, such as turnouts and gates, being of lumber. Wooden structures have been assumed because of the long distance from railroad transportation at the present time, and the probability that by the time they are old enough to require replacement railway transportation will have reached the project.

Pumping projects.—The cost of maintenance and operation of pumping projects is usually higher than for gravity projects, but not necessarily so, especially if long and expensive diversion canals are replaced by direct pumping from a lake or stream very close to the land to be served. On the other hand, the power for pumping must be purchased each year, or if the power plant is owned by the project it must be maintained and operated as well as the pumping plant. The machinery in these plants will wear out in time, and an additional amount must be set aside each year for depreciation in order to replace worn-out parts. There are very few data available covering actual operation and maintenance costs for pumping projects. In the 1912 report of the United States Reclamation Service are given the costs of operation, maintenance, and betterments for 26 projects in the United States partly or wholly completed. These costs are tabulated on page 140 in the Deschutes Project Report.

In the case of the Minidoka project in Idaho there were 40,615 acres irrigated by gravity and 29,623 acres by pumping, while the irrigable acres under each were 62,000 and 47,300 respectively. The costs as tabulated in the Deschutes report are for the irrigable areas. If these costs are based on the acres actually irrigated, we have the following:

Cost of operation and maintenance, Minidoka project, Idaho—1912.

	Irrigated.	Operation cost.		Maintenance cost.		Total cost per acre.
		Total.	Per acre.	Total.	Per acre.	
	Acres.					
Gravity	40,615	$16,758	$0.41	$18,366	$0.45	$0.86
Pumping	29,623	35,146	1.18	29,612	1.00	2.18

The probable yearly cost of operating the power and pumping plants for the project proposed is taken as follows:

Probable cost, pumping operation.

1 superintendent, 12 months, at $150	$1,800
1 assistant, power plant, 8 months, at $150	1,200
1 assistant, power plant, 6 months, at $100	600
1 assistant, pumping plant, 6 months, at $125	750
2 assistants, pumping plant, 6 months, at $100	600
1 lineman, transmission line, 6 months, at $100	600
Total	5,550

Probable yearly cost, power and pumping system.

Feature.	Probable cost in place.	Depreciation.		Maintenance.		Operation.	Total.
		Rate.	Amount.	Rate.	Amount.		
		Per cent.		*Per cent.*			
Power plant	$137,500	4	$5,500	1	$1,375	$2,700	$9,575
Transmission line	89,000	8	7,120	1	890	600	8,610
Pumping plants	112,500	4	4,500	1	1,125	2,250	7,875
Total	339,000	....	17,120	....	3,390	5,550	26,060

Probable yearly pumping cost per acre (27,000 acres), $0.97.

The operation and maintenance of the distributing canals and laterals should be materially less than for the area to be served by gravity canals, as the canals are comparatively short, and there will be no diversion headworks to operate and maintain. This cost should probably not exceed $0.75 per acre, and the total cost of maintenance and operation for the 27,000 acres to be served in North Warner Valley should probably not exceed $1.75 per acre when the units are fully developed, as against about $1 per acre for the lands to be served by gravity canals.

WHITE RIVER PROJECT.

GENERAL INFORMATION.

DRAINAGE BASIN.

White River drains an area of approximately 350 square miles lying on the eastern slopes of the Cascade Mountains in Wasco County, Oreg. White River Glacier, of Mount Hood, empties into the headwaters of White River, and during the warm months discharges large quantities of white sand from disintegrated tuff or soft rock. In a distance of 30 miles the entire watershed slopes from a general elevation of 5,000 feet in the Cascades to 800 feet along the Deschutes. The mountainous section, and by far the greater part of the watershed, lies within the Cascade National Forest, and is covered with a heavy growth of timber. The area to the south of White River around Wapinitia and Victor, locally known as Juniper Flat, does not discharge any surface water into White River, but drains directly into the Deschutes through Wapinitia Creek.

The lower portion of the basin outside of the forest reserve slopes toward the Deschutes at the rate of about 100 feet per mile. This area, now devoted almost exclusively to dry farming, with wheat as the staple crop, was originally a greasewood and bunch-grass country.

White River, from its junction with Clear Creek, flows through a canyon eroded in lava beds to a depth of from 500 to 700 feet below the general level of the surrounding country.

WATER SUPPLY.

Stream measurements.—Gaugings of stream flow in White River Basin have been made by the United States Geological Survey in cooperation with the State of Oregon during the period from 1912 to 1915, inclusive. Two gauging stations have been maintained, one on White River, in sec. 10, T. 4 S., R. 13 E., at a point about 1 mile above the mouth of Tygh Creek, and the other on Tygh Creek, in sec. 3, T. 4 S., R. 13 E., at a point about 1 mile above the mouth of the creek. Records of these measurements and gaugings are published in the Water Supply and Irrigation Papers issued by the Geological Survey and in Bulletin No. 4, office of State engineer for Oregon.

Present utilization of water supply.—Juniper Flat and the country about Smock and Wamic are underlain, close to the surface, with bedrock hardpan. No permanent subsurface ground water exists over these areas, and water for domestic use is hauled from surface streams. Quite recently a few bored wells have been sunk to a depth of about 400 feet and apparently into the main White River ground-water storage. The water rises only slightly in the wells, and is pumped and used for domestic purposes.

At various times during more than 20 years attempts have been made to divert the waters of Clear Creek to lands upon Juniper Flat. The Wapinitia Irrigation Co. has under construction some 9 miles of canal, which will divert water from Clear Creek in sec. 15, T. 5 S., R. 9 E., and discharge the same down McGovern Gulch and thence to Juniper Flat. It is stated by the company that when fully completed the ditch will carry about 100 cubic feet of water per second. The ditch as designed is to be of earth, will have a width of 9 feet at the bottom, 15 feet at the water surface, and a depth of 4 feet, with a grade said to be 2.65 feet per mile. As at present constructed its capacity is probably about 25 second-feet. The plan contemplates the utilization of Clear Lake as a reservoir to store the flood waters from the Clear Creek Basin.

The country about Smock and Wamic obtains water for domestic use and kitchen-garden irrigation from Boulder Creek, Gate Creek, Rock Creek, Threemile Creek, and Badger Creek. All ditches are small, and the waste of water by seepage is large.

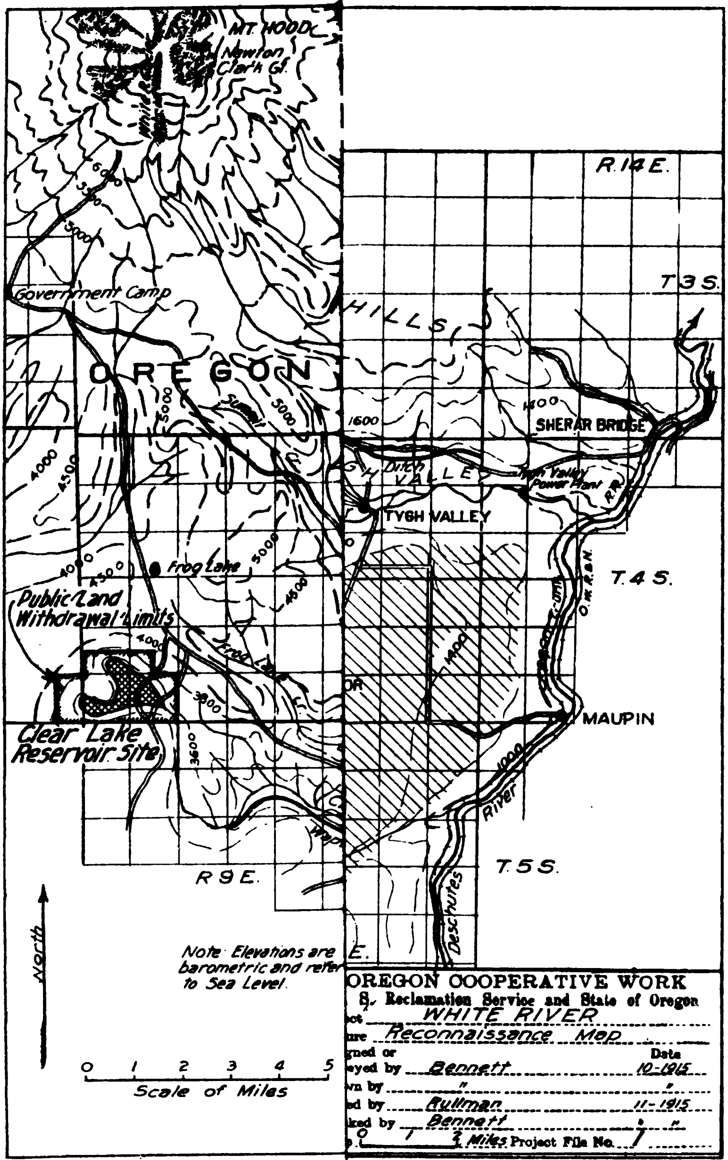
Water from Tygh Creek and Badger Creek is utilized to irrigate the bottom lands both along these creeks and on White River below the town of Tygh Valley. These lands at the present time furnish the only example in the White River Basin of irrigation which has been developed on a commercial scale.

Under the bench lands lying to the north of Tygh Creek and White River at the base of the Tygh Hills there is a more or less permanent flow of ground water, and numerous springs exist at the base of the Tygh Hills. No attempts to utilize this water for irrigation have been made, and no investigations to determine the possibilities of such use were undertaken at this time. A ditch diverting from Tygh Creek has been constructed to serve these bench lands, but it is not in use, owing to excessive seepage losses.

FIELD INVESTIGATIONS.

IRRIGATION.

The field investigations made for the purposes of this report, to determine the most feasible method of supplying water to the irrigable lands of the White River Basin, consisted of hand level and



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barometer observations of the elevation of controlling points necessary to the various schemes of development suggested, together with an examination of the physical characteristics of possible reservoir sites and canal locations essential to such schemes.

Threemile Creek.—It was suggested that water from Threemile Creek, Rock Creek, and Badger Creek be diverted and stored in a reservoir on Threemile Creek in secs. 7 and 18, T. 4 S., R. 12 E., for use in irrigating the bench lands between Badger Creek and Threemile Creek and those between Threemile Creek and Rock Creek. The area to be irrigated covers approximately 15,000 acres of land, with a net irrigable area of 7,500 acres. With sufficient storage the water supply from the creeks named would be ample to supply the demand from 7,500 acres of land. The probable cost of developing the reservoir site upon Threemile Creek, approximately $80 per acre of land served, together with a cost for distributing canal system of perhaps $15 per acre, a total of $95 per acre of land served, makes the scheme economically impracticable at the present time.

Tygh Valley lands.—It was also suggested that additional bench lands in Tygh Valley, at the foot of Tygh Hills, be irrigated with water from Badger Creek and Tygh Creek. The area which may be so served does not exceed 3,000 to 4,000 acres. The complication of water rights which will have to be adjudicated preliminary to the undertaking of such a scheme renders impossible at the present time any definite conclusion as to its feasibility.

White River diversion.—Attention was then directed to the main features of this report. It was found that water from White River could be diverted below Boulder Creek, in sec. 11, T. 5 S., R. 10 E., W. M., and utilized to irrigate the lands about Smock and Wamic to the north and the lands of Juniper Flat to the south of the river.

The land to which water could be diverted outside of the forest reserve and below the timber line covers a gross area of approximately 80,000 acres, with a net irrigable area of perhaps 40,000 acres. The length of diversion canal in the White River Canyon is short, and the irrigable land lies in a compact body, so that the cost of irrigating works will be relatively low. Such a scheme, however, will require that the White River power plant at Tygh Valley, with its water rights, be acquired.

SOILS.

The following report on soil conditions, by W. L. Powers, assistant professor of agronomy at Oregon Agricultural College, is based on a one day's study in the field, and must be regarded as very preliminary.

The soil on Juniper Flats is mainly residual and of one type, namely, brown very fine sandy loam. The color is light to dark brown, depending on distance from the foothills and consequent

rainfall. The soil texture is very uniform. There is considerable variation in soil depth. The subsoil is slightly lighter in color and heavier in texture than the surface layer. The average depth to basalt or volcanic ash hardpan is about 24 to 30 inches. A deeper phase occurs in places in the vicinities of Wamic and Smock, while a shallow, hummocky phase is found between Victor and Wapinitia and extending westerly to the foothills. This soil is comparatively free working and its usable water capacity and humus content are good for plateau land. A representative sample of soil collected in the southwest corner of sec. 5, T. 5 S., R. 13 E. was analyzed by Prof. C. V. Ruzek at the State experiment station, with the following result:

Mechanical composition of brown very fine sandy loam.

Sample.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Surface	1.14	2.40	5.92	21.28	26.08	29.42	13.76

Much of this soil has been farmed on the dry-farm plan for years and with fairly good success. In seasons of heavy precipitation some very good yields of grain have been obtained, while the average yield of wheat would be about 12 to 15 bushels per acre. Where irrigation has been practiced in a limited way near the creeks good yields of clover and on the deeper soil good crops of alfalfa have been secured.

The general contour maps of this land show that there is slope enough to insure fairly good drainage, while most of the depressions and "washes" seem to have natural outlets for the escape of excess water. There is no visible evidence of the presence of alkali in sufficient quantity to cause much trouble should careful irrigation be employed.

The irrigable acreage would be limited to about half the total area after excluding "rock beaks," scabby and shallow range land, and a few pockets and steep places. Perhaps 40 per cent. of the area is cleared at present. Practically all the land that is paying cost of production by dry-farming methods would be capable of fairly intensive cultivation under irrigation. On account of the limited soil depth a rotation of clover and timothy, row crops, and grain would be desirable under irrigation. With a season of about five months between frosts, fruit and vegetables can be produced on these lands to meet local needs.

On account of the rather fine soil texture with an appreciable content of clay and the rather dense substrata, furrow irrigation would

be more promising than flooding, and overirrigation would need to be guarded against. It seems reasonable to estimate that not more than two-thirds of the area should be in forage crops and not over one-half should be in meadow at one time. There should be a good proportion in grain and cultivated crops. If water supply is sufficient for all irrigable land to be reached, a duty at the land of about 24 inches per acre each season would seem to be a reasonable allowance under the conditions at hand. With an excess of land in proportion to water supply a somewhat higher duty would seem best.

Lack of moisture is the limiting factor in crop production on these lands, and irrigation should be welcomed here, as its proper use offers the best means for soil-moisture control. Irrigation would eliminate the necessity of summer fallowing and make possible more intensive diversified agriculture. It would make possible the keeping of more live stock and growing of legumes in rotation, whereby a more permanent system of agriculture would be established.

CLIMATE.

Records of temperature and precipitation have been kept at Wamic by the United States Weather Bureau since 1902 and are fairly complete.

Temperature.—The mean annual temperature is about 50°, with extremes varying from 25° below zero in the winter to 102° F. in the summer months. The daily range in temperature varies from 30° to 50°, according to the season, being higher during the summer than in winter.

Observations were taken by the bureau covering killing frosts during the period of record. During the growing months of some years intervals of a day or so have been recorded when minimum temperatures reached 32° or lower, and in general it may be said that on account of the elevation of the station, about 1,500 feet above sea level, and proximity to the mountains, killing frosts are possible any month of the year. These summer frosts, however, are of infrequent occurrence, in most years not appearing at all, and are rarely injurious to the hardier crops. The growing season extends on an average from about the middle of May to the latter part of September, covering, roughly, a period of about four and one-half months, and during several of the years of record has lasted a full five months.

Precipitation.—The mean annual precipitation for this period has been about 14 inches, much of which is furnished by the heavy snowfall during the winter months. There is a comparatively heavy rainfall during the spring months, and September and October furnish about the same amount per month as March, April, and May. The

mean precipitation, in inches, covering the irrigating season, May to September, inclusive, is as follows:

	Inches.
May	0.94
June	.69
July	.25
August	.36
September	1.04
Total	3.28

COST OF INVESTIGATIONS AND REPORT.

Following is the total cost and distribution of investigations to February 1, 1916. The estimated cost of completing and printing report, 1,000 copies, is $100:

Cost of investigation (Jan. 31, 1916):		
Paid by United States	$66.15	
Paid by Oregon	394.91	
Total		$461.06
Distributed as follows:		
Labor	275.72	
Supplies	5.55	
Other expenses	179.79	
Total		461.06

SUGGESTED DEVELOPMENT OF WHITE RIVER DIVERSION.

DUTY OF WATER.

For the purposes of this report there has been assumed a duty of 1.5 acre-feet of water delivered to the land during the irrigating season, with distribution as follows: May, 15 per cent; June, 25 per cent; July, 30 per cent; August, 20 per cent; September, 10 per cent. Assuming losses in diversion canals and distributing system to be equivalent to 25 per cent of the water diverted, the volume of water required for the season at diversion will be 2 acre-feet per acre irrigated. With these assumptions the water requirements are as follows:

Month.	Water diverted.	Water delivered to land.
	Acre-feet.	*Acre-feet.*
May	0.300	0.225
June	.500	.375
July	.600	.450
August	.400	.300
September	.200	.150
Annual	2.000	1.500

In addition, considerable water for domestic purposes will be required during the nonirrigating season. Such a demand, however, will not affect the water supply, as the use can be supplied from the natural flow of White River without affecting any storage water supply herein considered.

WATER SUPPLY.

Records of the discharge of White River for four seasons are available, gauged at a point about 1 mile aove the mouth of Tygh Creek. The surface inflow into White River between this point and the mouth of Boulder Creek, the point of diversion for the scheme here considered, comes from the north side of the river in Threemile Creek, Rock Creek, and Gate Creek, and as the water of these creeks will be diverted into the distributing system supplying the contiguous lands, it is still available as a supply for the scheme here considered. Moreover, a large portion of the low-water flow of these streams is at present diverted for domestic uses and is available for irrigation in addition to the flow of White River at the gauging station. There is probably considerable ground-water inflow into the river between the proposed point of diversion and the point of gauging. No measurements to determine the volume of this inflow have been made.

For the purpose of presenting figures in this report it will be assumed that there is available at the point of diversion below the mouth of Boulder Creek a volume of water equivalent to that shown by the gaugings just above the mouth of Tygh Creek. These records are as follows:

Monthly discharge of White River near Tygh Valley, Oreg.

Month.	Discharge in second-feet.			Total run-off in acre-feet.
	Maximum.	Minimum.	Mean.	
1911.				
June 18-30	378	263	302	7,780
July	259	127	179	11,000
August	139	102	112	6,890
September	244	102	143	8,510
The period				34,200
1911-12.				
October	189	127	139	8,550
November 1-15	498	127	245	7,290
January 13-31	2,050	1,120	1,370	51,600
February	1,520	510	918	52,800
March	485	300	361	22,200
April	845	410	562	33,400
May	1,120	560	768	47,200
June	670	320	491	29,200
July	320	180	233	14,300
August	210	150	167	10,300
September	252	150	170	10,100
The period		127		[1] 286,940

[1] Records incomplete.

Monthly discharge of White River near Tygh Valley, Oreg.—Continued.

Month.	Discharge in second-feet.			Total run-off in acre-feet.
	Maximum.	Minimum.	Mean.	
1912-13.				
October	228	156	175	10,800
November	360	156	236	14,000
December	510	174	201	12,400
January	510	196	301	18,500
February	435	205	272	15,100
March	785	244	331	20,400
April	845	560	694	41,300
May	1,120	560	839	51,600
June	975	410	586	34,900
July	410	244	309	19,000
August	244	149	186	11,400
September	190	136	144	8,570
The year	1,120	136	356	258,000
1913-14.				
October	510	136	191	11,700
November	292	157	193	11,500
December	226	190	213	13,100
January	975	244	497	30,600
February	588	220	358	19,900
March	725	410	551	33,900
April	725	410	568	33,800
May	560	320	450	27,700
June	320	210	269	16,000
July	210	150	175	10,800
August	156	138	147	9,040
September	238	130	149	8,870
The year	975	130	313	227,000
1914-15.				
October	228	130	162	9,960
November	228	156	188	11,200
December	210	150	179	11,000
January	485	150	192	11,800
February	535	210	293	16,300
March	535	245	369	22,700
April	785	320	468	27,800
May	385	262	300	18,400
June	245	152	191	11,400
July	176	136	155	9,530
August	142	110	123	7,560
September	126	82	98	5,220
The year	785	82	226	163,000

From these records of discharge the following table of irrigation demand and supply available from the natural flow of the river has been estimated, covering the demand assumed for the irrigation of 36,000 acres of land:

Irrigation requirement and supply available.

Month.	Demand for 36,000 acres.	1912		1913	
		Flow available for irrigation.	Deficiency.	Flow available for irrigation.	Deficiency.
	Acre-feet.	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*
May	10,800	10,800	0	10,800	0
June	18,000	18,000	0	18,000	0
July	21,600	14,300	7,300	19,000	2,600
August	14,400	10,300	4,100	11,400	3,000
September	7,200	7,200	0	7,200	0
Annual	72,000	60,600	11,400	66,400	5,600
Storage provided			15,000		15,000
Shortage			0		0

Irrigation requirement and supply available—Continued.

Month.	Demand for 36,000 acres.	1914		1915	
		Flow available for irrigation.	Deficiency.	Flow available for irrigation.	Deficiency.
	Acre-feet.	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*
May	10,800	10,800	0	10,800	0
June	18,000	15,200	2,800	10,500	7,500
July	21,600	10,800	10,800	8,400	13,200
August	14,400	9,000	5,400	7,500	6,900
September	7,200	6,900	300	6,200	1,000
Annual	72,000	52,700	19,300	43,400	28,600
Storage provided			15,000		12,000
Shortage			4,300		16,600

Records of the discharge of the streams contiguous to White River and throughout the Deschutes Basin show that the run-off for the year 1912 is below the average; that of 1913 is above the average; that of 1911 and 1914 is that of a low year which has a frequency of less than 1 year in 5 years; while 1915 is a year with a frequency of less than 1 year in 10 years.

If average annual storage to the amount of 12,000 acre-feet, with 3,000 acre-feet of carry-over storage, were supplied, there would result a shortage of 4,300 acre-feet, or 6 per cent, during the seasons of 1911 and 1914, and a shortage of 16,600 acre-feet, or 22 per cent, during the season of 1915.

CLEAR LAKE STORAGE.

A reservoir may be developed from Clear Lake, in secs. 29, 30, 31, and 32, T. 4 S., R. 9 E. The drainage basin has an area of approximately 8 square miles. Studies of the discharge of mountain areas in the Cascades at approximately the same elevation indicate that the probable average run-off from this area would be not less than 2,250 acre-feet per square mile. The run-off during the nonirrigating season is approximately 85 per cent of the annual discharge, so that the drainage basin of Clear Lake will have a probable average annual storage supply for irrigation purposes of 15,000 acre-feet.

It is probable that a reservoir of 18,000 acre-feet capacity to furnish an average net storage supply of 12,000 acre-feet of water will cost approximately $80,000, or $6.65 per acre-foot of water delivered at point of diversion.

DIVERSION CANALS.

The point of diversion proposed is at the mouth of Boulder Creek. The diversion dam will be so constructed that the pool above it will form a sand trap, and provision will be made for scouring the sand

deposits through openings in the dam. The canyon at the bottom is narrow, and a dam to raise the water from 30 to 40 feet would give sufficient slack water to cause the sand to be deposited. A concrete-lined diversion canal of approximately 130 second-feet capacity and 8 miles in length will be required to conduct the water from the point of diversion to the distributing system on the north side of White River, while a concrete-lined canal of approximately 230 second-feet capacity and 10 miles in length will be required to conduct the water from the point of diversion to the distributing system on the south side of the river.

Owing to the large amount of waste land and numerous culverts and stream crossings the distributing system will be relatively expensive.

COST OF CONSTRUCTION.

Following is the probable cost of the proposed storage, diversion and distribution to 36,000 acres, approximately 13,000 acres lying under the North and 23,000 acres under the South Diversion Canal:

Clear Lake storage, 12,000 acre-feet, at $6.65	$80,000
White River diversion dam and sand trap	75,000
North Diversion Canal, 130 second-feet capacity, 8 miles, at $14,000	112,000
South Diversion Canal, 230 second-feet capacity, 10 miles, at $19,000	190,000
Distributing system, 36,000 acres, at $15	540,000
Total	997,000

36,000 acres, at $27.70 per acre.

WHITE RIVER POWER PLANT—VALUE.

The diversion of the entire low-water flow of White River for irrigation purposes would require that either the hydroelectric power plant in Tygh Valley be abandoned or that sufficient auxiliary capacity be provided during the irrigating season to supply the demand over this period. In either case, damage liabilities result or direct purchase of the plant and water rights becomes necessary for initiating the scheme here considered.

The plant as at present equipped operates under a gross head of 142 feet and consists of one 1,900-horsepower Pelton-Francis turbine unit with a speed of 514 revolutions per minute, direct connected to a 1,250-kilowatt 2,300-volt 3-phase generator with attached exciter; two 1,100-horsepower Pelton-Francis turbine units, with speed of 225 revolutions per minute, direct connected to 500-kilowatt 2,300-volt 3-phase generators (one of these units is furnished with a belted exciter); one exciter unit, consisting of 40-kilowatt 125-volt 605-revolutions-per-minute generator direct connected to a Pelton-Francis turbine; four 3-phase 2,300–66,000-volt transformers and switch-

board. The station building is of rubble masonry, approximately 90 by 41 feet.

In the diversion dam and settling basin are approximately 2,200 yards of concrete masonry and 200 yards of rubble masonry. There are 768 linear feet of 60-inch wood-stave pipe and 320 linear feet of 60-inch riveted steel pipe, with head gates and controlling valves. The power is transmitted 26 miles to The Dalles, the transmission line consisting of three No. 3 copper-clad wires, necessary telephone wires, and ground wire carried on wooden poles. The flow of White River without storage, but with pondage above the dam, would permit the development at this plant of approximately 1,500 horsepower continuous output. The natural flow of the river would probably warrant the development of 3,000 horsepower continuous output and require the installation of an auxiliary plant capable of developing 1,200 horsepower continuous output. Such development with a 40 per cent load factor would require an installation at Tygh Valley capable of developing a maximum output of 7,500 horsepower, with an auxiliary plant capable of developing a maximum output of 3,000 horsepower.

The present plant is constructed to develop the equivalent of approximately 1,200 horsepower continuous output with 40 per cent load factor. No investigation to determine whether the present plant furnishes sufficient pondage to operate on this basis has been made for this report. During the season from July 1, 1914, to July 1, 1915, the plant furnished an output of 3,102,800 kilowatt hours with a load factor of 15.7 per cent.

Without assuming depreciation of equipment or the cost of reproducing a power plant in some other location capable of furnishing power to the market developed by this plant, the probable cost of replacing the present plant, including new equipment, is taken at $300,000. This amount would increase the cost of the irrigation proposed by approximately $8.35 per acre. It is probable, however, that the right to use the waters of White River as proposed without actually acquiring the power plant can be acquired from the power company for less than the cost of the plant.

WAPINITIA IRRIGATION CO.—VALUE OF DEVELOPMENT.

The development of the project herein contemplated will require that whatever rights the Wapinitia Irrigation Co. may have in the flow of Clear Creek and tributaries or for storage in Clear Lake be acquired. The value of the water rights controlled by the company is uncertain and indefinite.

The physical development of the irrigation system already constructed and under construction would cost approximately $3,000

per mile completed. The cost of these rights, whatever it may be, and the value of construction now done to the project proposed, or to any future development, must be added to the cost of construction and of power rights to obtain the total cost. It would seem that $300,000 may be a reasonable allowance for all rights necessary to be acquired. This amount would increase the probable acre cost from $27.70 for construction to approximately $36 per acre for the 36,000 acres.

ADDITIONAL POSSIBLE DEVELOPMENT—GATE CREEK STORAGE.

A reservoir site exists on Gate Creek in secs. 35 and 36, T. 4 S., R. 11 E., covering a portion of what is known as the "Hill Bench." The drainage basin above the reservoir site covers approximately 20 square miles, rises from an elevation of 2,000 feet to an elevation of 5,000 feet, and is heavily timbered. Gagings upon Tygh Creek, which drains a similar watershed, indicate that the minimum annual run-off from this watershed would not be less than 400 acre-feet per square mile, and for the nonirrigating season 340 acre-feet per square mile. If 20 per cent reservoir losses are assumed the drainage basin will furnish a minimum net annual storage supply of about 5,000 acre-feet at the Gate Reservoir site, at a probable cost of $10 per acre-foot of water delivered.

Additional water to the amount of 5,000 acre-feet would cover 2,500 acres of land and increase the total area of the project to 38,500 acres. The size of diversion canals will not be changed by this increase in irrigable area.

The acre cost to develop this additional area would be the cost of Gate Reservoir storage taken at $20 per acre of land, plus the cost of distributing canals at $15 per acre, or a probable cost of $35. It is apparent that, with a development cost of $10 per acre-foot or less, storage which may exist upon Gate Creek and Threemile Creek may be utilized without increasing the development cost per acre of irrigable land. The acre cost of maintenance for small reservoirs is comparatively large where the reservoirs are isolated and require the exclusive time of an attendant, and in such cases would be of doubtful economy. Nevertheless, the course of development of the project would be such that a diversion of the natural flow of the river would be developed before storage was provided, and by the time storage became necessary many of the indefinite factors controlling the course of such development would be known.

Other possible storage reservoir sites may exist in addition to those herein discussed, capable of developing storage at or below a cost of $10 per acre-foot, but none were discovered during the reconnoissance survey of the basin undertaken for this report.

LAND AND WATER WITHDRAWALS.

Lands.—In compliance with the agreement between the United States and the State providing for these investigations, public lands have been withdrawn from entry for Clear Lake Reservoir as shown on sheet No. 1, White River project. No other public lands have been withdrawn from entry for this project.

Waters.—In compliance with this same agreement, waters required for this project have been withdrawn from appropriation as follows:

All unappropriated water of Threemile and Gate Creeks, tributary to White and Deschutes Rivers, was withdrawn by the State engineer on January 22, 1915, under application No. 4073.

All unappropriated water of White River and its tributaries was withdrawn by the State engineer on November 11, 1915, under application No. 4624.

Twelve thousand acre-feet of water of White River and its tributaries to be stored in Clear Lake Reservoir were withdrawn by the State engineer on November 11, 1915, under application No. 4625.

FACTORS AFFECTING COST OF DEVELOPMENT.

The item of cost of development contained in the price which must be paid to acquire the White River power plant and other rights will remain the same, whatever the area of land which may be developed. This item of cost per acre of irrigable land therefore decreases as the area of irrigable land increases, and vice versa.

As a general rule the cost per acre of irrigable land, to construct the distributing system, increases with an increase of the area irrigated and decreases with its decrease. This cost, however, may be considered to be practically constant within the possible limits of size of any project which may be developed here. For this project, moreover, the cost per acre of irrigable land, to construct the diversion canals, will increase with a decrease of area and decrease with its increase. The variations in cost per irrigable acre of the distributing system and diversion canals for larger or smaller areas irrigated partially offset each other.

The elimination of all storage would reduce the irrigable area to approximately 15,000 acres. The cost of the reservoir would be eliminated, and the probable total cost of a 15,000-acre irrigation system for the north side of the river would be approximately as follows:

White River diversion dam and sand trap	$75,000
North Diversion Canal, 150 second-feet capacity, 8 miles, at $15,500	124,000
Distributing system, 15,000 acres, at $14	210,000
Purchase price White River power plant	300,000
Total	709,000

15,000 acres, at $47.20 per acre.

The area upon Wapinitia Flat that could be served under the above conditions would be less than for the north side of the river, as the water from Boulder Creek, Gate Creek, Rock Creek, and Threemile Creek would not be available for diversion to the south side of the river.

If we assume that the area which may be served upon Wapinitia Flat is 14,000 acres, the probable cost of an irrigation system for the south side of the river would be approximately as follows:

White River diversion dam and sand trap	$75,000
South Diversion Canal, 140 second-feet capacity, 10 miles, at $14,750	147,500
Distributing system, 14,000 acres, at $14	196,000
Purchase price White River power plant	300,000
Total	718,500

14,000 acres, at $51.30 per acre.

It is evident that storage of from approximately 10,000 to 20,000 acre-feet at a price of from $5 to $10 per acre-foot is essential to a minimum construction cost of irrigation works on the bench lands in White River Basin.

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS.

SUMMARY.

A summary covering both the Warner Valley and White River projects appears in the form of a synopsis in the fore part of this report.

WARNER VALLEY PROJECT.

CONCLUSIONS.

It appears from the investigations and studies made:

(1) That the mean water supply available for irrigation in Warner Valley is somewhat less than 200,000 acre-feet, that the minimum run-off is less than half this amount, and that the extreme maximum run-off is possibly two or three times this amount.

(2) That the area of lands in the valley which can be reclaimed by drainage and by being pumped to, with lifts of 50 feet or less, exceeds that for which there is sufficient water supply.

(3) That the irrigation problem for the amount of water available is as to choice between draining and thus reclaiming bottom lands and pumping to higher lands.

(4) That in the former case the matter requiring most careful consideration is that of disposing of excess waters in years of maximum discharge into the valley.

(5) That nevertheless the project to reclaim bottom lands by drainage and irrigation is the more desirable.

(6) That because it is not practicable to develop the project by small stages the project can not be considered attractive even at the comparatively low probable cost except by the use of money at a rate of interest less than 6 per cent.

(7) That because the majority of the lands are held in large tracts the initiative for development should come from the owners.

(8) That the waters of Twentymile Creek are not essential to the project, and are not even desirable except in years of comparatively low run-off.

(9) That the relief of the valley from the waters of Twentymile Creek in years of high discharge is of more value in development of the valley than their use during years of low run-off.

(10) That Coleman Valley offers a reservoir site for disposition of from 60,000 to over 100,000 acre-feet of waste water for evaporation, and that Cowhead Lake offers a similar reservoir for waste water in

connection with storage for irrigation supply for Cowhead Lake project in California for perhaps 75,000 acre-feet.

(11) That Big Valley Reservoir site offers a very cheap storage site for irrigation purposes for 50,000 to 100,000 acre-feet.

(12) That these several reservoir sites in connection with storage by regulation in Crump, Hart, Flagstaff, and Bluejoint Lakes will take care of excess flood waters in all except perhaps the years of most extreme run-off.

(13) That commercial power development is practicable to the extent of 2,000 to 4,000 horsepower whenever a commercial market is developed.

RECOMMENDATIONS.

It is recommended:

(*a*) That the Warner Valley project be treated by the United States and the State as a feasible project whenever the owners of the lands under it express a desire to have development undertaken and when railway transportation into the valley can be assured.

(*b*) That in the meantime records be kept of discharge of the various streams entering the valley, together with the discharge of Deep Creek at Big Valley.

(*c*) That the public lands of Big Valley and Coleman Valley Reservoir sites be withdrawn from entry by the United States for storage purposes.

(*d*) That unappropriated waters of Deep Creek and tributaries be withdrawn from appropriation by the State for the proposed project.

(*e*) That applications to the State engineer's office for appropriation of water from Twentymile Creek, or any of its tributaries, to be used in California, be granted on condition that provision be made for storage of at least 75,000 acre-feet of flood waters in Cowhead Lake and for diverting into Cowhead Lake 75 per cent of the average maximum discharge of Keno, Rock, Twelvemile, and Fifteenmile Creeks.

WHITE RIVER PROJECT.

CONCLUSIONS.

From the preliminary investigations made of this project it appears probable:

(1) That the water supply from White River and its tributaries is sufficient for the entire irrigable area considered.

(2) That further development from White River than now exists will require the purchase or control of the White River power plant.

(3) That the natural flow of White River without storage is sufficient in ordinary years for the development proposed on the south side of the river, provided the power plant is eliminated.

(4) That storage is required to supplement the low water flow for irrigation of the area proposed on the north side of the river.

(5) That Clear Lake is the best storage site available, if sufficient tributary run-off proves to be available.

(6) That it is reasonable to expect the run-off available to be from 12,000 acre-feet to 18,000 acre-feet per annum.

(7) That whatever rights are held by the Wapinitia Irrigation Co. must be acquired.

(8) That the soils are adapted, with irrigation, to intensive cultivation, but that frosts probably limit the value of irrigated lands to a considerable extent.

(9) That therefore the development of the project will likely not prove successful at the probable cost unless money for construction can be obtained at a low rate of interest, certainly not to exceed 6 per cent.

RECOMMENDATIONS.

It is recommended:

(*a*) That the project be regarded by the United States and the State as feasible if assumptions as to run-off available from Clear Lake are confirmed by subsequent records.

(*b*) That a gauging station be maintained at the outlet of Clear Lake.

(*c*) That, pending the obtaining of several years' records of supply available, the unappropriated waters of White River and its tributaries be held withdrawn from appropriation by the State.

(*d*) That public lands at Clear Lake be continued withdrawn from entry by the United States for storage use in connection with the project.